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POLAR EXPLORATION

By WILLIAM S. BRUCE
LL.D., F.R.S.E.

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POLAR EXPLORATION

BY

WILLIAM S. BRUCE

LL.D., F.R.S.E.

LEADER OF SCOTTISH NATIONAL ANTARCTIC ("SCOTIA") EXPEDITION, 1902–4; DIRECTOR OF SCOTTISH OCEANOGRAPHICAL LABORATORY, EDINBURGH

LONDON

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PREFACE

I AM glad to have this opportunity of presenting to a wide public an outline of the essential facts and problems of Polar Exploration. It is not more than introductory to a more comprehensive book which I hope to write when some leisure is afforded from the more real work of exploration and research. I must also note that it is not intended to be in any way a history of Polar Exploration.

The book is simply a "traveller's sample," revealing to some extent what is in the great "warehouse" of the Polar Regions. It is based, *firstly*, on the author's personal experiences during nine polar voyages—two to the Antarctic Regions, viz. in 1892–93 and 1902–04; seven to the Arctic Regions, viz. in 1896–97, in 1898 (two), in 1899, 1906, 1907, and 1909; *secondly*, on many personal conversations with living polar explorers during the past twenty years, including several conversations and correspondence with the veteran Sir Joseph Dalton Hooker, O.M., who accompanied Sir James Clark Ross on his ever-memorable Antarctic voyage from 1839–1843, as well as conversation and correspondence with the leaders and many

members of the staffs of every recent polar expedition.

Consequently the personal note predominates, and those parts of the Polar Regions which the author has visited are dealt with in greater detail than those which he has not yet had an opportunity of visiting. But the attempt is made to deal with facts and problems that are of general rather than local interest.

I have to acknowledge kindly help in the production of this little book. Dr. R. N. Rudmose Brown has revised the text, especially the botanical section, and framed the index; Mr. J. Y. Buchanan, Mr. R. T. Omond, and Mr. J. Bolam have revised the sections dealing with the Physics of the Sea, Meteorology, and Astronomy. Mrs. Bruce has been my amanuensis throughout.

WILLIAM S. BRUCE.

Scottish Oceanographical Laboratory,
Edinburgh, 1911.

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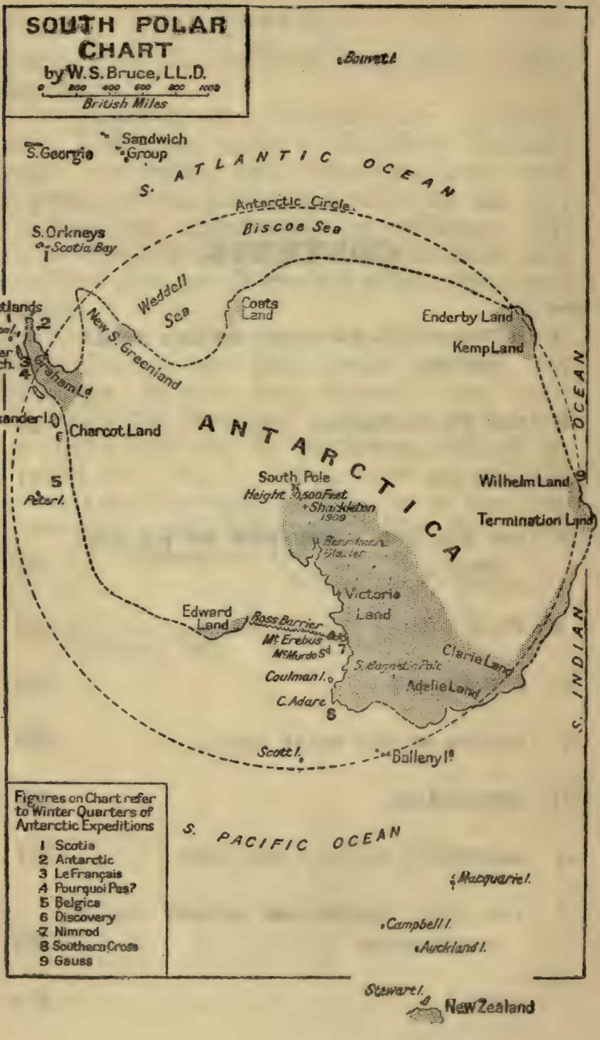
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by W. S. Bruce, LL.D.
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British Miles
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S. Georgia
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S. ATLANTIC OCEAN
Antarctic Circle
Biscoe Sea
S. Orkneys
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NORTH POLAR CHART
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British Miles
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CANADA
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SWEDEN
RUSSIA
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Faröe Is.
Shetland Is.
BRITISH ISLES
North Sea
GERMANY

DEDICATED BY PERMISSION TO

SIR JOSEPH DALTON HOOKER, G.C.S.I., O.M., F.R.S.,

NATURALIST TO THE BRITISH ANTARCTIC EXPEDITION,

1839 TO 1843, IN ADMIRATION OF HIS DEVOTED

SERVICES TO ANTARCTIC EXPLORATION

DURING SEVENTY-TWO YEARS

POLAR EXPLORATION

CHAPTER I

ASTRONOMICAL FEATURES OF THE POLAR REGIONS

From the earliest days of European civilisation it has been customary to define the direction of the sun at noon as well as the opposite direction. South and north are the terms that have been used by north-western Europe: hence North Pole for that end of the earth's axis towards which Europe stretches, and South Pole for the other end of the axis.

Now there are very definite peculiarities of these two mathematical points, and I give a few of these to set the reader thinking.

1. The sun is continuously above the horizon for six months, from our spring to our autumn equinoxes, and continuously below the horizon for the other six months.

2. But there is only one time, namely noon, because all longitudes converge at the North

Pole: whether it be light or dark it is always noon, because the sun is always due south.

3. Though there is only one time there are different seasons, because these depend on the position of the earth in its orbit and on the inclination of the polar axis to the plane of the ecliptic.

4. The apparent path of the sun is an ascending spiral from the vernal equinox till the summer solstice, and a descending spiral from the summer solstice till the autumnal equinox. Thus it is possible to take meridian altitude of the sun during the whole summer six months at the North Pole, at any moment, or at every moment, no matter where the sun is in the spiral. Exactly the same thing may be said of the moon when she is north of the Equator.

5. The greatest possible altitude of the sun above the horizon is about 23½ degrees (actually at Greenwich mean time, 1911, June 22nd, 2^h p.m., 23° 27′ 9″·8). It reaches this altitude only at that date.

6. The constellations never set at the North Pole, their apparent paths (neglecting their own very tiny movements) being in circles, round the Pole; like the sun, they are always south of the North Pole.

7. When standing at the North Pole it is impossible to look in any other direction along the earth's surface but south. To the left or

to the right, behind or in front of the person standing at the North Pole the direction is always south.

These conditions apply equally to the South Pole, except that the terms north and south have in every case to be reversed. It is very important to get a proper grip of these facts if one is to have a proper conception of where the Polar Regions are, and to account for various special phenomena peculiar to these two parts of the earth.

Theoretically it is convenient to define the Polar Regions as those areas that lie round about the North Pole and round about the South Pole, within the Arctic and Antarctic Circles, which are defined by being those circles of latitude where the sun on midwinter-day does not rise and where on midsummer-day it does not set.

In contrast to the tropical regions, where the sun is always vertically overhead at some place at noon on two days (at the north and south limits on one day) every year, and always reaches in every part an altitude exceeding about 43 degrees, in the Polar Regions the sun is never more than 23½ degrees above the horizon. On account of this great obliquity of the sun's rays in the Polar Regions the sun has less heating power and the regions are colder, while in winter intense cold prevails because of the entire absence of the sun.

Having now obtained a general idea of the position of the Polar Regions on the earth's surface let us pass on to consider their general features. And the Antarctic Regions are considered first, because it was there, about twenty years ago, that I first received my polar baptism and first learnt what the Polar Regions were.

CHAPTER II

THE POLAR REGIONS

I HAVE defined the Antarctic Regions as lying within the Antarctic Circle, that is, south of 66½° S. latitude, but in 1892, on board the Scottish whaler *Balæna*, I found that this definition broke down, for we fell in with polar conditions before we reached latitude 60° S., some 500 miles south-eastward of Cape Horn, in the neighbourhood of the South Shetland Islands. My impressions of the circumstances are as vivid to-day as then, and more vivid, perhaps, than many other even more striking incidents during that and subsequent voyages.

Sailing south-eastward from the Falkland Islands across the breezy southern ocean, we came into weather, although it was mid-summer, having temperatures about freezing-point. This cold weather was accompanied by fairly frequent fogs which occasionally were very dense, till one day, when we were about 80 miles north-east of the South

Shetland Islands, the fog divided, opening up a vista at the far end of which a gleam of sunshine revealed a huge shadowy iceberg—brilliantly white. Sailing on we came nearer to the berg, which was several miles off when we first sighted it, and found it to be a mass of ice which probably rose fully a hundred feet out of the water and was about half a mile long. The top of it looked as flat as a billiard table, and the sides were vertical white cliffs; some cracks, mostly vertical and lenticular, were strongly defined, because in them was to be seen the most brilliant and intense blue one can imagine. At the water-line the ice cliff was worn by the lashing of the relatively warm waves (32·3° F.), and here and there were caves at sea-level where green intermingled with intense blue. Into these caves the water rushed with a resounding roar, until each cave was a seething cauldron, and in some cases the spray from these caves rose high into the air. The sea was literally swarming with Cape pigeons and blue petrels, while great finner whales played and spouted in the vicinity of the ship. The Cape pigeons were so numerous that, on putting a small piece of fat over the side of the ship, one could catch them quite easily with an angler's landing-net. The silk tow-net showed that the water was swarming with a small shrimplike creature called *Euphausia*, several

species of smaller crustacea, and some diatoms; the diatoms blocked the meshes of the silk and made the tow-net slimy. In the evening we sighted another berg to leeward, and at night two other icebergs on either bow of the ship. The sun set only a little to west of south, and a light band of brilliant sky stretched along the southern horizon much the same as is seen in Scotland in June. During that night we passed several bergs in the fog, which came down and enveloped us again; we also met some nasty irregular ragged bits of hard clear ice, each about the size of a cottage, called "growlers" by Arctic seamen on account of the sound they made when rolling in the waves. These growlers are literally floating rocks which would rip the sides out of an ordinary iron steamer. We were truly in the Antarctic Regions, although more than 300 miles north of the Antarctic Circle. For this and other reasons I prefer to define the Antarctic Regions as being bounded by the average limits of floating ice. This line is almost entirely north of 60° S., except to the south of the Indian Ocean and to the south of New Zealand and Tasmania, where it dips to the southward. It trends farthest north in the South Atlantic Ocean, reaching about 50° S. to the south of Cape Colony, and 55° S. to the south-east of the Falklands. Within this limit we find

the conditions very much as I have described them on that first day when, on board the *Balæna,* we fell in with the ice.

But besides defining the limits of Antarctic ice, this boundary is useful in other respects, for it includes the whole of the continental land mass of the Antarctic Regions, which at several points protrudes beyond the Antarctic Circle, notably at Graham Land and Wilkes Land. It also includes most of the really typical Antarctic islands, such as South Georgia, the Sandwich Group, South Orkney or Powell Islands, South Shetlands, Bouvet Island, Balleny Islands, etc. It also excludes continental terminations of South America and South Africa as well as Australia. The Antarctic Regions are of exactly opposite character to the Arctic Regions; whereas in the Arctic Regions there exists a polar basin of considerable depth, surrounded by an almost complete ring of continental land, composed of the northern parts of Europe, Asia and America, in the Antarctic Regions we have an extensive continental land mass surrounded by a continuous ocean. So far we know little of this vast continent, which is probably as large as Europe and Australia combined. What coast-line has been discovered was nearly all discovered before any of the more recent expeditions sailed to the south. It is interesting to note that the depth of the North

Polar Basin is more or less equal to the height of the Antarctic continent.

Ross, Wilkes, D'Urville, Biscoe, Kemp, Palmer, Johnson and Morell all made important land discoveries previous to 1844. Since that time the most important land discovery was Coats Land, which not only filled up a gap between Enderby Land and New South Greenland, but which placed the edge of the Antarctic continent 500 miles farther north than Murray and others had mapped it. Of the interior of the Antarctic continent we know but little; the pioneer journey of Armitage, at an altitude of 9,000 feet, gave us our first insight into the nature and extent of the continental ice cap of which we have further knowledge from the journeys of Scott, Shackleton and David. (*The Heart of the Antarctic*, Sir E. H. Shackleton: London, 1910.)

There are two theories regarding the Antarctic continent: one, that it is one continuous land mass; the other, that it is divided by a channel from the Weddell Sea to the Ross Sea. To my mind all the evidence points to one land mass, and for the following reasons, although it should be noted that Prof. Penck and others adhere to a belief in two. Looking at the map we will find that the outline of the south of South America is almost the same as that part of the Antarctic continent known as Graham Land; each

terminates in a pointed extremity which is largely broken up into clusters of islands and tends to turn towards the eastward; each has a group of islands lying to the eastward—South America the Falkland Islands, and Graham Land the South Orkneys. We notice also that whereas the west coast of South America is rugged and broken up into many islets and channels, the east coast is of simpler outline. These features also hold good for Graham Land. Looking at the general sculpture of these two lands we find that South America has a high rugged mountain range on the west, parallel with the coast, and broad plains of low elevation on the east; the same features hold good in the description of Graham Land, as far as it is known. The most recent explorations of Dr. Jean Charcot still further emphasise these resemblances. Finally, looking at the geology, we find that both the west coast of South America and the west coast of Graham Land are made up of the same class of folded rocks, composed of gneisses, granites, etc., and that along each coast there is a tendency for active volcanoes to appear; but on the east coast of both lands there are sedimentary rocks of more recent origin with plateau formation. In fact, the only marked difference that occurs is in the glaciation, which is accounted for by difference of latitude.

Now give the globe a half turn round its axis and compare Victoria Land and its islands with Australia and its islands. We will find the outline of Victoria Land on its east coast has a remarkable resemblance to the east coast of Australia. Lying off the coast of Australia we have New Zealand and other islands which have their counterpart in the smaller islands off Victoria Land, notably Balleny Isles, Possession, Coulman, and Ross Islands. The east coast of Australia is flanked by a great mountain range parallel to the coast, which slopes away to the westward, and Victoria Land has exactly the same feature. Geologically both Australia and Victoria Land are plateau formations of similar type and age. The volcanic character of New Zealand compares with the volcanic islands of Balleny, Possession, Coulman and Ross; all are on folded mountain ranges.

There is a further striking feature. The whole of the west coast of South and North America has the same character in being skirted by parallel folded mountain systems, bearing a certain number of volcanoes. This general Eastern Pacific character also holds good for the west coast of Graham Land. So, also, the general type of the Western Pacific appears to be carried over into Victoria Land, and it is obvious that both these systems on the east and on the west of the

Pacific Ocean are essentially the same except for secondary modifications. In consequence, we have all coasts of the Pacific, as far as they are known, of exactly similar formation in all *essential* respects. To my mind, therefore, there can be no doubt that this type of coast is continuous along the Pacific coasts of Antarctica, and that the mountain system of Victoria Land and its islands links up with the mountain system of Graham Land, almost certainly excluding the possibility of a break to the east of Victoria Land by a channel across to the Weddell Sea. Neither Penck nor Darwin appear to have given sufficient consideration to the principles and characters of different coastal types in reaching the conclusions they have regarding a channel or deep inlet under the Ross Barrier across the Antarctic continent, slightly to the Pacific side of the South Pole. Evidence obtained from the distribution of ice, deep-sea deposits, and marine fauna all bears out this contention of a continuity of the land.

This great mountain chain forms, in fact, the backbone of Antarctica, and probably more or less follows the sea coast between Victoria Land and Graham Land just as it does in those lands themselves.

Very little is known of the continental coast-line to the south of the Atlantic and the Indian Oceans, but there is every reason to

believe that the coast-line in these parts will resemble in general character the coast-lines of the rest of the lands bordering on the Atlantic and Indian Oceans: that is to say, that the coasts will not be precipitous except at points where mountain ranges cut them at right angles to the coast, and, meeting the sea, form cliffs and capes. The general formation of these will probably prove to be of the plateau type truncated by the sea.

The little we do know of the coast-line in this region certainly does not refute this opinion. The earliest discovery of continental coast-line in this region was by two American sealers, Captains Johnson and Morrell in 1823, who reported a large tract of land to the south of the South Orkneys, which Johnson called New South Greenland. Biscoe in 1831 discovered a large tract of land from about 12° 22′ E. to Enderby Land, in about 52° E. The next important discoveries were those of Wilkes and D'Urville in 1840, to the south of the Indian Ocean—Adelie Land and Côte Clarie. The other land-falls of importance to the south of the Atlantic and Indian Oceans have not been until recent years, when von Drygalski discovered Wilhelm Land, which is evidently a south-western extension of Termination Land, and when Coats Land was discovered by the Scottish expedition. Considerable scepticism is shown, especially

in England, regarding the reported land of Morell and Johnson; but not in Scotland, for the investigations of the *Scotia* undoubtedly tend to suggest the presence of New South Greenland, as do also the observations made on board the *Erebus* and *Terror* in 1843. There is little doubt that Graham Land is joined to Coats Land by New South Greenland, and that the Weddell Sea does not extend very far to the south in that region. Again, there appears to be little doubt that Coats Land is continuous with Enderby Land, and that the latter, through Kemp Land and Wilhelm Land, is continuous with Wilkes Land. Wilkes described high land, and so did Biscoe; and these capes may well be the termination of mountain ranges more or less at right angles to the coast; but, generally speaking, the coast of Antarctica does not appear to be lofty on the Atlantic and Indian Ocean sides. Coats Land, for instance, is entirely iceclad and slopes gently towards the sea, mostly terminating in an ice cliff possibly 100 feet high and at several points sloping right down to sea-level. Several of those on board the *Scotia* confidently affirmed that they could see mountain peaks in the distance, but there is considerable doubt if that was actually the case. (*The Voyage of the Scotia*, R. C. Mossman, J. H. H. Pirie, and R. N. Rudmose Brown: Edinburgh, 1906, p.

236.) If there were mountains they must have been at a great distance; all that I could see from the ship along the 150 miles of coast-line that we mapped was the iceclad land rising inland in undulating slopes to an unknown height.

There are several other points to be considered, but what I wish to emphasise here is, that there is round about the South Pole a continent of enormous size, filling almost the whole region within the Antarctic Circle, and that it is probably one, and not two land masses. This continent has an area of about five and a half million square miles, an area equal to that of Europe and Australia combined. Outside this great continent, almost entirely iceclad, lies the Great Southern or Antarctic Ocean. In the far south of this there is relatively fine weather broken intermittently with terrific storms—blizzards from Antarctica. In the more northern parts of this ocean there is continual stormy weather from the west, which causes high seas to run, and earns for this part of our globe the name of the "roaring forties" and the "shrieking fifties." That part of the Great Southern Ocean which falls within the average limit of floating ice we will here consider as being within the Antarctic Regions.

It is not proposed to discuss here the history of Antarctic exploration, which has recently

been done so ably by Dr. H. R. Mill in *The Siege of the South Pole*, but I wish to give in more or less detail, as far as limited space will allow, an account of Antarctic seas and lands. This can perhaps best be done by dwelling more especially on those parts that I have seen myself, namely, Graham Land, South Shetlands, South Orkneys, Coats Land, and the Weddell and Biscoe Seas, and by giving a more general account of parts I have read of or heard of by conversation with other Antarctic explorers, including the veteran Sir Joseph Hooker who sailed with Sir James Clark Ross in 1839, and others who have visited the Antarctic Regions since.

The striking incident of meeting ice at sea for the first time in one's life, and especially falling in with those giant Antarctic icebergs —grim sentinels of the Antarctic—produces even in most matter-of-fact individuals a sense of wonder and awe. Their stupendous size, their exquisite architectural composition, more magnificent than the temples and pyramids of Egypt, more overpowering in solemnity than the Sphinx—make the most thoughtless think for a moment of the Power that controls the forces of nature.

During some years there are many more icebergs in the great Southern Ocean than during others, and the summer of 1892–93—that is to say, our northern winter, November till Feb-

ruary—was such a year. On December 23rd and 24th, 1892, on board the *Balœna*, we fell in with a great host of bergs in the vicinity of the Danger Islets; they were all of great size, some being 3 or 4 miles long; at one time I counted as many as sixty from the deck, while more could be seen from the mast head. They were all of similar height, about 100 or 150 feet high. Each one was table-topped. At one time we passed through a regular street, lined on each side with towering bergs, each a temple in itself, now Doric, now Egyptian, each perfectly carved and shaped, each purer and whiter than the other, glittering in the sun, pearl grey in the shade and rich blue in the clefts and caves which pierced their sides. This street or avenue was several miles long, indeed some individual bergs were fully half-a-mile in length; side avenues opened into this main avenue. Sometimes we sailed into an open piazza, sometimes past the end of so narrow and winding a passage that it would have been dangerous even for one of our ship's boats to attempt to navigate it. Presently we came out of this closely packed group of bergs into the open sea, where there were still many bergs scattered from horizon to horizon. Besides bergs we now fell in with pack ice, amongst which were "bergy-bits," that is, small irregular bits that had become detached from the bergs. Here and

there a seal lay on the pack, sleeping or gracefully lifting its head to look at our ships with its large dark eyes, little dreaming of the cruel fate that was to befall his companions a few days later. Fussy penguins, with their white breasts and black backs, jumped out of the water on to the pieces of pack ice, and by their rather harsh cry and quaint attitudes appeared to be entering a protest at being disturbed in this unseemly manner. There was almost a perfect calm, and despite a dense canopy of cloud overhead the horizon was clear and bright. At midnight on Christmas Eve, in latitude 64° 13′ S. a little to the east of Mount Haddington, we were stopped from pushing any farther to the south because of solid field ice that stretched across our bow. Afterwards the edge of this ice was examined and was found to stretch for about 250 miles north-eastward without a break through which any of the three Scottish whalers, that were there together at the time, could have passed. It is true that, with united attack, these stout ice-armoured ships could have penetrated some miles through this ice by charging and recharging, by sawing and blasting, and, if there had been a sign of open water at the back of the ice, it might have been worth doing this to see if the whale, reported by Ross in 1843 and described by him as greatly resem-

bling the Bowhead Whale, was seeking safe retreat there. But all the evidence indicated that there was no water at the back and to the south of this ice, but that it continued in a more or less solid field till it came up against land, which was invisible from the ship's deck, except to the W. and S.W., and even from the crow's nest at the ship's mainmast-head.

In technical whalers' language we " fastened on to the floe " that night and lay there during the whole of Christmas Day, the only day of rest we had for the next two months. The scene was of wonderful beauty, and I cannot do better than quote the graceful description by the able artist-chronicler of the voyage.

" Those who have felt," says Burn Murdoch (*From Edinburgh to the Antarctic*, by W. G. Burn Murdoch), " the peace of a summer night in Norway or Iceland, where the day sleeps with wide-open eyes, can fancy the quiet beauty of such a night among the white floes of the Antarctic. To-day has passed, glistering in silky white, decked with sparkling jewels of blue and green, and we thought surely we had seen the last of Nature's white harmonies; the evening came, pensive and soothing and grey, and all the white world changed into pale violet, pale yellow, and rose.

" A dreamy stillness fills the air. To the south the sun has dipped behind a bank of pale grey cloud, and the sky above is touched

with primrose light. Far to the north the dark, smooth sea is bounded by two low bergs, that stretch across the horizon. The nearest is cold violet white, and the sunlight strikes the farthest, making it shine like a wall of gold. The sky above them is of a leaden, peacock blue, with rosy cloudlets hanging against it—such colouring as I have never before seen or heard described. To the westward, across the gulf, we can just distinguish the blue-black crags jutting from the snowy lomonds. Little clouds touched with gold and rose lie nestling in the black corries, and gather round the snowy peaks. To the south, in the centre of the floe, some bergs lie cold and grey in the shadow of the bank of clouds. They look like Greek temples imprisoned for ever in a field of snow. A faint cold air comes stealing to us over the floe: it ripples the yellow sky reflection at the ice-edge for a moment, and falls away. In the distance a seal is barking—a low muffled sound that travels far over the calm water, and occasionally a slight splash breaks the silence, as a piece of snow separates from the field and joins its companion pieces that are floating quietly past our stern to the north—a mysterious, silent procession of soft, white spirits, each perfectly reflected in the lavender sea.

"Nature sleeps—breathlessly—silent; perhaps she dreams of the spirit world, that

seems to draw so close to her on such a night.

"By midnight the tired crew were all below and sound asleep in their stuffy bunks. But the doctor and I found it impossible to leave the quiet decks and the mysterious daylight, so we prowled about and brewed coffee in the deserted galley. There we watched the sun pass behind the grey bergs in the south for a few seconds, and appear again, refreshed, with a cool silvery light. A few flakes of snow floated in the clear, cold air, and two snowy petrels, white as the snow itself, floated along the ice-edge.

"A cold, dreamy, white Christmas morning —beautiful beyond expression."

These lines recall to me that wonderful scene, more charming and restful than many another Arctic and Antarctic scene I have seen since. The dignity, the solemn grandeur, the colour, and the marvellous silence all helped to leave a lasting impression upon me, and, in spite of many discomforts, difficulties, and dangers that I have had to face since in the north and the south, it is this wonderful picture and others like it that call me back again.

I have given this picture as an artistic presentation, and now I am going through the rather ruthless process of analysing the subjects in the picture. In the first place, every one will agree that we were, without

doubt, in what might be fairly described as the Antarctic Regions, although, when the *Balœna* lay anchored to impenetrable ice on Christmas Day we were outside the Antarctic Circle by two and a half degrees, or 150 miles. The first definition therefore defining the Antarctic Regions as lying within the Antarctic Circle breaks down completely, just as it did ten years later when on board the *Scotia* we met with impenetrable ice not very far south of latitude 59° S. to the east of the South Orkneys, or when, during the winter of 1903, the *Scotia* was frozen up for eight months in Scotia Bay, which is situated between 60 and 61 degrees south latitude.

Mention has been made of icebergs, of field ice, of floe ice, and of pack ice. Let me explain what these terms mean. It has been shown that there is a great area of land, probably one great continent, round about the South Pole. This continent is surrounded by the Great Southern Ocean, and, over the region occupied by that ocean, within the average limit of floating ice, there are even in summer time wintry conditions; so much so that most of the precipitation that occurs is in the form of snow instead of rain. In midsummer, when cruising in the vicinity of the Antarctic continent, blizzards off the land cause the temperature to fall even below zero Fahrenheit, and in winter on

Antarctica itself a temperature has been recorded as low as 68 degrees below zero Fahrenheit, or 100 degrees of frost. The lowest air-temperature has been recorded at Verkhoyansk in Siberia, namely, – 90° F., or 122 degrees of frost. From this it will be seen that, as most of the Antarctic land lies well within the Antarctic Circle, practically all precipitation must be in the form of snow, and that little melting takes place except where the sun gets very favourable play. On black rocks the sun's heat may be absorbed, and in sheltered corries, where there may be considerable melting, resulting in the formation of small burns and tarns.

On the rocks a few lichens will grow; on softer, more crumbly, and flatter expanses a few mosses may thrive, and amongst these mosses and in the tarns a few minute forms of animal and vegetable life will flourish, which have sharp alternate spells of activity or passivity according as the temperature is above or below the freezing-point.

CHAPTER III

LAND ICE

UNDER the conditions of low temperature which have been described, even if there is only a very slight snowfall in the heart of Antarctica, there must be a constant accumulation of snow upon the land. This snow by its own incumbent weight gets compressed into ice, which fills corries and glens, and covers any flat land there may be with a great depth of solid ice. But the accumulation cannot go on indefinitely, and the ice begins to flow, first down the steeper glens, then down even the least inclined stretches of the land, forced by the great mass of ice always accumulating from behind. It may even get pushed over flat if not actually rising ground, and eventually reaches the sea. If the sea be shallow it may push out a considerable distance from the land, ultimately floating free from the bottom. Fresh snow is all the while falling, and adding to the whole. Blizzards come and drive the powdery loose snow from one place to another, and the hard-driving wind binds the powder

into solid ice. Imagine all this on an enormous scale! Not over an area of a dozen or a hundred, or even a thousand square miles, but over an area as large as Europe and Australia combined, then we have a picture of what is happening over the length and breadth of Antarctica! The ice thus accumulated from snowfall, thus consolidated from loose snow into solid ice by pressure, gets pushed ultimately into the sea. Let me indicate what happens by referring for a moment to a phenomenon with which all of us are familiar. A snowstorm whitens all the country round and every roof has a coating of snow some six inches thick. The snow gets bound together and remains a more or less solid covering on the roof, till one day it slips off from various causes in irregular pieces, all about six inches thick and perhaps several feet across, and crashes down on the roadway beneath. But if the eaves of the roof dipped into water at that level, then this great sheet of icy snow would, when slipping from the roof, float off on the surface of the water. The floating sheets of icy snow—"floating ice islands"—would be of various areas, but they would all be flat-topped, and of a uniform thickness of six inches, the sides would be more or less perpendicular, and the greater part of the thickness would be below the surface of the water, the amount depending

on the solidity of each sheet of icy snow, but possibly one inch might be above water to five inches below. Magnify your roof, magnify your ice covering which has slipped off the roof and floated off into the water, magnify your snowfall of a single night into that of more than a thousand years, make every inch of thickness 100 feet, and you have models on a scale of 1 to 1,200 of Antarctic icebergs, at least as far as shape is concerned. The mode of formation also is somewhat similar to that of the Antarctic icebergs, although probably the great ice-fields that come flowing over extensive stretches of gently undulating or more or less flat land, and even what would be shallow sea were the ice not there, are fed not only by the intermittent falls of snow year after year and by the drift brought from the mountains and inland ice, but also by glaciers which act as feeders to these low-lying ice-fields, and which keep on pushing the whole mass seaward until great flat-topped pieces, exactly similar in shape to the flat-topped snow islands from the roof, float out to sea.

One of these great ice-fields lies to the south of New Zealand, terminating in an ice cliff in the Ross Sea, which is usually known as the Ross Barrier. This great barrier was discovered by Ross in 1840, and was visited by him during two successive seasons. It

has been now visited by several expeditions during recent years, especially by those under the leadership of Scott and Shackleton. This ice cliff, varying in height from almost sea-level to about 100 feet above the sea, stretches in an east and west direction between Mounts Erebus and Terror and Edward Land for a distance of nearly 300 miles. It is quite easy to imagine that pieces many miles in length and breadth might break off and float out to sea, as well as almost innumerable smaller pieces from a mile or two in length and breadth to only a few feet. This is exactly what does happen, and it certainly must occur in other parts of the Antarctic Regions besides the Ross Sea. Those countless bergs seen by us on board the *Balæna* in 1892–93, and again those seen by all on board the *Scotia* during her two cruises in the Weddell Sea, as well as those that drifted past the South Orkneys for eight months during the winter of 1903, and those seen by Charcot between 70° W. and 124° W., certainly did not come from the Ross Barrier, but from similar barriers, perhaps even more extensive than the Ross Barrier. Other barriers must occur elsewhere in the Antarctic Regions to account for the host of table-topped bergs that are scattered all over the Great Southern Ocean, and indeed Nordenskjold has described one on the east coast of Graham Land. The greater size

of the bergs on the Atlantic Ocean than on the Pacific side of Antarctica indicates the greater scale of the ice-sheet towards the Weddell Sea than towards the Ross Sea. Moreover, after the reports of the latest expeditions, it appears probable that the larger and more numerous bergs that occur to the south of the Atlantic and Indian Oceans are not wholly comparable in their formation and structure to those found in the Ross Sea, in the neighbourhood of the Ross Barrier.

The whole question of the Ross Barrier and a barrier described by Nordenskjold on the east coast of Graham Land, which he calls an "ice-terrace," is most interesting. Buchanan and Nordenskjold have pointed out that these barriers, or ice-terraces, are composed of névé, not glacier ice, and with the Graham Land Barrier this especially appears to be the case. Névé, however, precludes the idea of flow, and we have the definite record of Scott that Barne, on visiting a dépôt Scott had laid down, found that it had "moved on." "Thirteen and a half months," says Scott, "after the establishment of the dépôt, he measured its displacement, and found it to be 606 yards. And thus almost accidentally we obtained a very good indication of the movement of the Great Barrier ice-sheet." (*The Voyage of the Discovery*, Captain R. F. Scott, vol. ii, p. 300 : London, 1905.)

Doubtless, the Ross Barrier is fed considerably from the southern glaciers that run into it. Speaking of the discharges of the glaciers from the névé of the inland ice plateau, Scott says, " From observations which I have mentioned one must gather that the movement of this most northerly of these discharges is very slow, but judging by the movement of the Barrier, the southern ones are more active."

Now the only good channels by which glaciers run into this Barrier, and that are of importance and that come down from the Inland Ice-sheet or Inland névé over which Scott, Shackleton, Armitage, and David have led expeditions, probably come into it at half-a-dozen so-called inlets, such as Skelton, Mulock, Barne, and Shackleton Inlets, and the largest and most definite feeder known is the great glacier that Shackleton discovered and travelled up from the Barrier to the Inland Ice, namely, the Beardmore Glacier.

But the ice that pours out of this evidently rapid-flowing and huge glacier is about 360 nautical miles from the face of the cliff of the Ross Barrier. Now, according to Scott's estimated rate of flow of the Barrier at 606 feet in thirteen and a half months, it would take nearly 1,200 years for that ice to reach the Barrier face. Meantime the whole glacier—or should it be called ice-field ?—is accumulating

ice by snowfall and by drift from the surrounding mountains and plateaux, and must therefore be chiefly and, indeed possibly, wholly composed of this in the form of névé, but with this marked character, that it is a moving, and not a stationary, névé. At some future time, with more space at my disposal, I propose to further discuss this point, because a general definition of a névé is ice that collects in a lofty plain, from which glaciers flow out but which does not actually flow itself. The structure of névé ice is also distinct from that of glacier ice, the grain of which, in each case, is the leading feature. The flow of the Ross Barrier is, I believe, different from that of an ordinary glacier which comes running and tumbling down a gully or a glen, like water in a river down a river course, for in this case it comes over a low stretch of flat or gently shelving land or shallow sea and is ultimately afloat. It is rather pushed from behind than moving forward by its own gravitation. The flow is probably different also in this respect, that, like a rapid river, there is a sort of rotatory movement of the ice of a glacier which is plastic by virtue of its disintegrated grains, each surrounded with a film of saline water, whereas very little of such movement would occur in the case of the barrier ice, and consequently the marks of stratification remain visible in the bergs which are calved from it.

Except for a certain amount of glacier ice, which comes in from the feeders mentioned, the Ross Barrier is made up almost entirely of successive years' additions of snow and drift that fall upon it and accumulate in definite layers. The simile, therefore, that I have already given of the snow layer on a roof is all the more striking, only it is not the accumulation of snow of a single fall, not even of snow of a single year, but probably of snow that has fallen, say, during a thousand years.

It would not do to pass by Nordenskjold's important observations with regard to his "ice terrace" at Graham Land, and it is best to quote his own words (*Antarctica*, Dr. Otto Nordenskjold: London, 1905) as follows: "At our noonday rest I was nearly falling into a broad crevasse, but said nothing of the matter, in order not to make the others anxious. But all of a sudden the ice became more uneven, and at 5 p.m. our march came to a sudden and unexpected end in front of a canal-like crevasse, some 20 metres (65 feet) broad and almost as deep, which seemed to run in towards the land as far as the eye could reach. This crevasse was of great interest, as it gave us a very clear idea of the inner structure of the ice. The same splendid stratification could be seen here as that which often occurs in the large icebergs, thus proving that the

ice had been formed of layers of snow deposited, during long periods, the one upon the other, and being, too, a new proof of the transition, found in these regions, from glacier to sea ice. I think, too, that the Antarctic icebergs need not necessarily have their origin on land, but that they can also be built up on a base of sea ice in shallow water near the land."

Nordenskjold's idea that Antarctic icebergs may be built up on a base of sea ice is not altogether new, for Captain Cook previously made that suggestion, though without the great scientific qualifications that Nordenskjold has for expressing such an opinion, and also without the knowledge of the existence of these barriers or ice-terraces that have been discovered in the Antarctic Regions by Ross and Nordenskjold since Cook's voyage. But from my experience in the Polar Regions during twenty years I cannot conceive of these Antarctic bergs being built up from a base of sea ice.

There appears to be little doubt, however, that the Ross Barrier is to a great extent afloat. But Sir George Darwin's "guess" "that the bay behind the barrier stretches past the South Pole and to the east of it as far as latitude 80°" is dangerous. All the evidence at our disposal from observations taken in the region of the Weddell Sea con-

demns the idea that there is "an arm of the sea through to Weddell's Sea." (*Tidal Observations of the British Antarctic Expedition*; 1907. Sir G. Darwin.)

The question is a most intricate and difficult one, and cannot be properly solved until one or more expeditions set themselves to work in definitely making examinations of the ice of the different layers of the barriers, of the different layers of the bergs that have been shed from them, and various detailed measurements, and, what is perhaps as important as anything, the demarcation of the exact extent of these barriers, and a detailed survey of their surface as regards level. From the information we have at hand, it is very difficult to assert with certainty that the altitude of the Ross Barrier, when it emerges into the Ross Sea, is exactly the same as it is in 84° S., in the vicinity of the Beardmore Glacier.

It can be imagined that bergs of almost any length might be broken off from such a barrier as the Ross Barrier, and, as a matter of fact, bergs of enormous size have been recorded by many voyagers to the South Seas. Even allowing for exaggeration due to difficulty in gauging their length, bergs of several miles in length, up to 20 or 30, certainly do occur. A single glance at the ice chart for the Antarctic Regions published by the Ad-

miralty will confirm this statement. On board the *Balœna* and the *Scotia* we saw many bergs at least 4 miles long: on one occasion, on the *Balœna*, we measured a berg 12 miles long, and on another occasion the *Balœna* steamed at the rate of 5 knots for 6 hours along the face of a berg, which made the length of it fully 30 miles. Some bergs have been recorded of very much greater height than any I have seen, though the records are doubted by some Antarctic explorers of recent years, but in bad weather and in those tempestuous seas it is easy for such errors to occur, though it may be possible to have bergs considerably more than 150 feet high in the Antarctic if, by weathering, one of these flat-topped bergs should become tilted up on end. These gigantic bergs have at times been described as ice islands, and by the inexperienced mistaken for land.

There is another class of icebergs in the Antarctic Regions that are rather overlooked and lost sight of by being overshadowed with so large a number of these great flat-topped bergs: these are bergs that are similar in every respect to those of the Arctic Regions. They are formed by much smaller and irregular pieces of ice breaking away from the snouts of glaciers similar to those found in Spitsbergen and other Arctic lands. These are only formed in smaller masses of land like the

South Orkneys or those parts of the continent where relatively small individual glaciers run directly from the mountains into the sea, as they do at the northern extremity of Graham Land, at the South Orkneys, and several other places.

The reader should now have a clear conception of what bergs are and how they are formed. He will see that they are a product of the land, and that they are composed entirely of fresh-water ice. They may be likened to great ships, dwarfing the greatest liners and battleships into beggarly insignificance; they sail forth to the open ocean drifted by deeper currents rather than the wind, moving to and fro with the tide; blizzards and stormy seas lashing them, they drive onward with the currents of the sea, checked only by a contrary tide and helped onward by a favourable one; onward they go head to wind and head to sea, it matters little to them! Should some smaller berg be driven against one of these leviathans, it is dashed to pieces against its icy cliffs, only with the sacrifice of a few chips falling off and around its victim; should a field of floe ice be driven by the wind against it, the floe is broken into fragments, whilst pack ice divides and passes by on either side. They drive onward and northward all-conquering and resistless, and then venture forth into warmer seas. These seas are the most

tempestuous in the world, and the presence of so much ice in water of a higher temperature not only encourages fogs, as does also the variation of the temperature of the air and water, but is exceedingly dangerous to ships navigating there; especially as in these latitudes there are always dark nights of greater or less duration the whole year. But this is the beginning of the end: rotted by the warmer winds and seas, gutted out with caves up which great waves rush in wild confusion into the very bowels of these monsters, the bergs get undermined, turn turtle, and break up into many smaller bergs and thousands of smaller irregular pieces. These irregular chips get still more weathered, and assume most fantastic shapes, and are hard as flint. They are the "growlers" and the "bergy bits" that we have already spoken of.

Many an iron ship has had its side or bottom ripped out with growlers, and many a wooden ship has had its wooden walls "stove-in" with them, and nothing more has been heard of them or their living human freight. No chance for these poor wretches, even if a few managed to scramble wet, cold, and benumbed into a ship's boats. No hand to help, no one to hear their last cry of agony. If this is the power of a "growler," what chance has a helpless sailing-ship driving

before a gale with a monster berg on its lee? Her end must be a battering to death against its solid ice cliffs.

Even with ships specially constructed for ice-navigation, the greatest care has to be exercised. I have seen a relatively small piece weighing hundreds of tons falling off one of these great bergs; a smaller more weather-beaten berg splitting in two; and, on another occasion, a berg turning turtle. In each case a great wave was generated, and had our ship been in too close proximity it would certainly have resulted in serious damage and probable loss of life, if not total destruction. Several Antarctic ships have had narrow escapes when navigating, under force of circumstances, during dark nights in the vicinity of these great bergs; the serious collision of Ross's ships among a chain of bergs during a hard gale on a dark night, was an instance as notable as their miraculous escape. On this terrible night the *Erebus* was trying to weather a berg when it was observed that the *Terror* was running down upon her. It was impossible for the *Terror* to clear both the *Erebus* and the berg; collision was inevitable. Ross graphically describes the incident, and says, "We instantly hove all aback to diminish the violence of the shock; but the concussion when she struck us, was such as to throw almost every

one off his feet; our bowsprit, fore-topmast, and other smaller spars, were carried away; and the two ships hanging together, entangled by their rigging, and dashing against each other with fearful violence, were falling down upon the lofty berg under our lee, against which the waves were breaking and foaming to near the summit of its perpendicular cliffs. Sometimes she rose high above us, almost exposing her keel to view, and again descended as we in our turn rose to the top of the wave, threatening to bury her beneath us, whilst the crashing of the breaking upper works and boats increased the horror of the scene. Providentially they gradually forged past each other, and separated before we drifted down amongst the foaming breakers, and we had the gratification of seeing her clear the end of the berg, and of feeling that she was safe. But she left us completely disabled; the wreck of the spars so encumbered the lower yards, that we were unable to make sail, so as to get headway on the ship; nor had we room to wear round, being by this time so close to the berg that the waves, when they struck against it, threw back their sprays into the ship. The only way left to us to extricate ourselves from this awful and appalling situation was by resorting to the hazardous expedient of a stern-board, which nothing could justify during such a gale and with so

high a sea running, but to avert the danger which every moment threatened us of being dashed to pieces. The heavy rolling of the vessel, and the probability of the masts giving way each time the lower yard-arms struck against the cliffs, which were towering high above our mast-heads, rendered it a service of extreme danger to loose the mainsail; but no sooner was the order given, than the daring spirit of the British seaman manifested itself—the men ran up the rigging with as much alacrity as on any ordinary occasion; and although more than once driven off the yard, they after a short time succeeded in loosing the sail. Amidst the roar of the wind and sea it was difficult both to hear and to execute the orders that were given, so that it was three-quarters of an hour before we could get the yards braced bye, and the maintack hauled on board sharp aback—an expedient that perhaps had never before been resorted to by seamen in such weather: but it had the desired effect; the ship gathered stern-way, plunging her stern into the sea, washing away the gig and quarter boats, and, with her lower yard-arms scraping the rugged face of the berg, we in a few minutes reached its western termination; the 'under tow,' as it is called, or the reaction of the water from its vertical cliffs, alone preventing us being driven to

atoms against it. No sooner had we cleared it than another was seen directly astern of us, against which we were running; and the difficulty now was to get the ship's head turned round and pointed fairly through between the two bergs, the breadth of the intervening space not exceeding three times her own breadth; this, however, we happily accomplished; and in a few minutes, after getting the wind, she dashed through the narrow channel between two perpendicular walls of ice, and the foaming breakers which stretched across it, and the next minute we were in smooth water under its lee.

" A cluster of bergs was seen to windward extending as far as the eye could discern, and so closely connected, that, except the small opening by which we had escaped, they appeared to form an unbroken continuous line; it seems, therefore, not at all improbable that the collision with the *Terror* was the means of our preservation, by forcing us backwards to the only practicable channel, instead of permitting us, as we were endeavouring, to run to the eastward, and become entangled in a labyrinth of heavy bergs, from which escape might have been impracticable, or perhaps impossible."

The *Challenger*, too, had uncomfortable experiences on February 24, 1874, when the late Professor Moseley relates " it blew a

gale, with dry drifting snow obscuring the view and rendering it impossible to see for a greater distance than 200 or 300 yards." After having failed to fasten on under the lee of a berg, "either a back current set the ship on to the berg, or the berg itself was drifting towards us with the wind more rapidly than was expected. A collision ensued and the jibboom was forced against the side of the berg and broken, together with some parts of the rigging in connection with it. The end of the jibboom left a starlike mark on the sloping wall of the berg, but had no other effect on the mass. The men who were aloft reefing the topsails, came down the back stays helter-skelter, expecting the top-gallant masts to fall, but no further damage ensued.

"The weather became worse," continues Moseley; "we were in rather a critical position. We were surrounded by bergs, with the weather so thick with snow that we could not see more than a ship's length, and a heavy gale was blowing. The full power of steam available was employed. Once we had a narrow escape of running into a large berg, passing only just about 100 yards to leeward of it by making a stern-board, with all sails aback, and screwing full speed astern at the same time. The deck was covered with frozen powdery snow, and forward was coated with ice from the shipping of seas."

The following day the *Challenger* had forty icebergs in sight at noon.

At the end of March 1903, whilst looking for a harbour in the South Orkneys, we had four anxious days and nights on board the *Scotia*, navigating amongst bergs in dirty weather, and on the 22nd of March 1903 narrowly escaped shipwreck by collision with an iceberg. The nights at this time were very dark and of full twelve hours' duration, and it was blowing almost continually with fog and driving snow, especially when we came near the land. All day in such weather we would approach the land cautiously, looking in vain to find a safe harbour where the *Scotia* might winter; and at night, to prevent being driven ashore, we would steam out to sea. To the north of the South Orkneys at this time the sea was clear of pack ice, but it was full of bergs, and the greatest vigilance had to be shown. On the afternoon of Sunday, March the 22nd, while endeavouring to discover Lethewaite Strait, the squalls became exceedingly violent, accompanied by snow and very heavy, blinding drift from the high mountains of Coronation Island. Suddenly, there seemed to be a lull in the wind, and the sea became smooth as glass—an ominous sign, for we had assuredly come under the lee of a berg or high land. "Hard-a-port!" was Captain Robertson's swift order, and we swung round,

and in doing so there loomed up on the port side the grim icy cliff of a huge berg, which almost grazed our yard-arms. Nothing but the able handling of the ship by my officers and crew, and their long experience of navigating among ice could have saved us from a most deadly collision, if not shipwreck: soon after, as the drift diminished, we sighted another berg to leeward, and a little later, when it cleared, we found we were completely surrounded by bergs.

Having dealt with Antarctic icebergs, let us now turn our attention to the other forms of ice I have mentioned. Apart from icebergs, all other Antarctic and indeed Polar ice is a product of the sea and not the land.

CHAPTER IV

SEA ICE AND COLORATION OF ICE AND SNOW

At almost any time during even a summer cruise, when there is a perfect calm and when the sun is low during the night, there may be found under the shadow of loose pieces of ice, which gently rest upon a glassy sea, newly-formed fine ice spicules floating on the surface: these ice spicules are dissipated when the rays of the sun play once more on the surface of the water. If the temperature of the water be taken at such a time it will be found to be about 29° F., which is therefore clearly about the temperature at which the polar seas begin to freeze. That is to say, about 3° F., below the freezing-point of fresh water, which, as the reader will know, freezes at 32° F.

Now, if the temperature of the air falls considerably below 28° F., say to 15° F., these ice spicules or crystals increase very rapidly, and the whole surface of the sea becomes covered with a considerable layer of them,

which is known by polar seamen as "Bay ice." If there is a snow shower the snow mixes with these crystals and does not melt, but becomes part and parcel of this bay ice and is termed "slush." This may increase in thickness up to, say, 3 or 4 inches. If wind arises and sea is thrown into waves it is found that the crystals are all separate and that the bay ice or slush is quite mobile, but it is not so mobile as the water without crystals, the shape of the waves being less sharp. In fact, the waves have an oily motion in a slush-covered sea. If one tries to pull in a boat, the pulling is found to be very heavy, and even the way of a large ship with good steam power is seriously impeded. The water is, in fact, "gluey." The "slush" may include in it any small fragments of ice that are floating on the sea at the time. Should there be a sudden lowering of the air-temperature with a heavy fall of snow, then the slush is formed in greater part of snow crystals, but has essentially the same qualities, except that it may be slightly more disintegrated than simple bay ice.

If the weather is stormy and the water is considerably disturbed, though the slush increases considerably the spicules of ice and snow are evidently more or less free, though the water continues to become more and more gluey and waves become less and less

pronounced: but, if it is calm weather, the crystals become entangled in somewhat fixed positions, and adhering to each other the slush becomes a plastic crust on the surface, even less than an inch thick. This newly-formed sheet of ice is known as "Bay ice," because naturally it forms more easily in sheltered bays. Any new ice, from the thinest film to ice of, say, 6 to 8 inches in thickness, is termed "Bay ice." An ordinary wooden ice ship forges its way through it by continuously steaming ahead. Until this bay ice is some 4 or 5 inches thick it has a black appearance, being more or less translucent. But when it becomes thicker and more securely frozen together with some sharp frost it becomes whiter.

A ship steaming through "Black ice" cuts through it as through a sticky scum, leaving a blacker lane of water astern, exactly the width of the ship, which does not close up until frozen over again. But through the thicker and more rigid "White ice" as the ship steams ahead a long split is formed ahead of her, through which she is able to forge her way. This more completely formed white ice is often easier for navigating a ship through, because it is more brittle than the thinner black ice, which is gluey in texture.

Now, if the water remain calm very striking and beautiful developments occur. There is always some horizontal motion in the surface of the sea, even if it is a glassy calm, owing to currents or change of tide or other causes. For one of these reasons, the surface water spreads itself out by flowing away from one position a little more rapidly than the surface water at its rear is making up upon it, possibly on account of the dividing of the tides or a slight air blowing in a contrary direction in one quarter to that in the other; or it may be due to one of those delicate air-currents that one sees looking over a glassy Scottish loch, which by mere chance enables one fairy yacht to move ahead of its becalmed fellows not many hundred yards distant. Then the crust divides into thousands of hexagonal discs from about an inch to several feet in diameter, the diameter increasing with the thickness of the bay ice; in between the discs, the shiny black lines of water broaden into wide lanes, and the surface of the sea is like a patchwork quilt. Now, some slight disturbance occurs, a little wind or tide, which causes the surface waters to come together again, the more or less hexagonal ice discs hustle together, their delicate sides and corners are crushed and broken, and are curled up by the pressure. Thus they become subangular discs, each

with a flat interior and a bruised turned-up edge, like a pancake. Again the motion of the surface of the water, due as often as not to tide, separates these discs; again they are hustled together and bruised and get their edges still more turned up. This goes on continually, and meanwhile the discs are thickening and solidifying with the continued low temperature. This ice is known as "Pancake ice."

By continued and increased frost the edges of the pancakes get frozen together and the whole surface of the sea has a continuous sheet of ice, only to be broken up again, however, into fresh though larger hexagons, which in turn are hustled together and form magnified pancakes many feet in diameter. These require greater force, as they increase in thickness and solidity, to break up again, until eventually they remain together in one great solid sheet which nothing but a heavy gale and a tremendous sea will break into pieces. Those great sheets of ice, often many miles—it may be even hundreds of miles—in extent, are known in general terms as "Floes," or "Field ice," "Floe ice" usually being employed when they are less extensive, the term "Field ice" for ice that stretches unbroken beyond the limits of the eye from the crow's-nest.

A "Land floe" is a floe that is formed

next the land and that remains fast to the land, if the weather is light, during, it may be, the whole of the following summer. Such a floe continues to increase in thickness during the second winter, but it is unlikely that the weather will be so favourable as to allow this "land floe" to survive a second summer. But, on the other hand, the first year's floe may rot away entirely during the first summer after its formation. I saw this happen in Franz Josef Land during the summer of 1897 to a land floe that I had watched from its birth to its disintegration, from the time the first "bay ice" was forming on the calm surface, through the period when the ice was thick and solid, until it had rotted entirely away.

The surface of such a primitive floe is as level as the surface of the sea, and before the winter snows and the drift from the land or other parts of the same floe cover it, it has the texture of a good Brussels carpet on the surface. It is never smooth or glassy like the ice formed on the surface of fresh water. One cannot curl, slide, or skate upon it. Ski stick on it and sledges will not glide over it. The surface is sticky, and even at low temperatures it wets through the thin soles of fur boots and proves very destructive to them. It has a sort of efflorescent appearance and a saltish taste. It is, in fact, the saltest layer

of the floe, which may freeze to a thickness of 5 or 6 feet; sometimes less thick when strong currents flow under its surface, sometimes of greater thickness in sheltered lochs and bays. But while the surface of the floe is very salt, if a piece of ice be taken out of any intermediate part it is found to be relatively fresh, certainly not nearly so salt as the sea itself.

I shall return later on to this interesting question of the saltness of sea ice, at present I wish to deal only with general naked-eye structure. It can be seen that this ice is much more plastic than fresh-water ice. Fresh-water ice is relatively brittle, even in thin layers. Fresh-water ice, of the thickness of about 2½ or 3 inches, will bear the weight of a man, but a child's foot would sink through sea ice of similar thickness, as if going through a layer of tough glue. You can push a stick through it, and a seal can push his nose and head through from below to get a breath.

Now, if there be a slightly undulating swell running under this new ice one sees the ice following the same motion, but to a less marked degree. But the thicker and more solid the ice, the more resistance is offered, until there comes a point where the sea-swell is killed. On the other hand, if the motion of the sea be more violent the more solid

fields and floes are strained to breaking-point, and split up, first into small floes of a mile or two or at least several hundreds of feet in diameter, and these in their turn being repeatedly strained, twisted, and hurled in the wild confusion of the storm against each other, against bergs or against a rocky shore, get broken up into thousands of pieces only a few feet in diameter. This broken-up ice is known as "Pack ice." During the breaking up of the ice, the floes crush together and their edges are broken and curled and piled with the pressure. Farther away from the open sea, well in among the solid floes, this pressure is very heavy and one floe may run over and another under the other. The edges of an extended crack, that has formed in a weak place, curl over and over and a long ridge of broken-up ice is the result. These ridges are known as "Pressure ridges," and the irregular piles of ice of which they are formed, or similar piles of ice formed along the edges of smaller free-floating floes, or the piles of ice that are formed by the pieces of pack ice that get heaped upon each other are known as "Hummocky ice" or simply "Hummocks."

This irregular conglomeration freezes together again almost immediately if it is winter, and indeed it needs very tempestuous sea and weather conditions to break up the

solid continuous floe in winter. The usual time of break-up is in the spring, when with rising temperatures the sea ice is becoming rotten.

"Brash ice" is ice that is usually met with on the outskirts of the pack. It is the remnant of the fray, being composed of a chaotic collection of small subangular pieces from a few feet in diameter to an inch or two, which have been broken off all kinds of larger pieces during their battle with the wind and sea and with one another.

In the autumn, especially with the increasingly stormy weather, the pack ice is jammed up together. Irregular pieces of all sizes and shapes are huddled together: fragments of the new floe of the previous year, fragments of hummocky ice, fragments of ice that have been thickened by the frosts of two or three winters, fragments of over-ridden floes, bergy bits broken off icebergs, and brash ice. All this ice, each piece different from its neighbour, is driven together by the wind and sea, and is formed into "streams" of ice, which always lie at right angles to the wind and which may be many miles in length. Loose pieces of ice in the open sea, on the weather side of these "streams," are driven before the wind more quickly than the stream itself, and are ultimately driven into the stream and form part

of it. Pieces on the lee side, however, do not readily get driven off, as they are protected from wind and sea by the whole breadth of the stream, thus the stream increases in size. The stream which lies farthest to windward drives faster and is driven on to the stream under its lee. Stream joins stream, and as the storm increases we have a formidable "body of ice" many miles in width as well as breadth. This pack drives on and on, resistless and all-conquering, until it is checked in its steady career by meeting another solid pack, or by the land, or, in the Antarctic, by one of those giant bergs. Confusion arises; the ice piles itself high up on the land—great heaps of even 20 or 30 feet high being formed. Here it may remain for many a year before it is finally dissipated. I have seen this occur more than once. If it is driven against the vertical cliff of an Antarctic berg or against the face of a barrier like the Ross Barrier, it will curl up the face of the cliff and fall back again upon itself in a confused heap. If a ship is between it and the land, the ship will be hurled ashore and no human effort can do anything to avert such a disaster. This has frequently happened. In recent times, the *Alert* was driven ashore with the pack at Rawlings Bay in Kennedy Channel, in 1876, and the *Stella Polaris* at Teplitz Bay, in Franz Josef Land, in 1899.

A ship may be lying against a floe, perhaps fastened to a land floe, when the pack drives down upon it and it is caught; or, more deadly still, between two floes, when the pack drives down upon the outer one, drives it on, and the ship is crushed to matchwood between the two, unless—as happened with the *Scotia* off Coats Land—she is so constructed that when the "nip" comes she rises to it, and is heaved out on the top of the ice, the floe and pack driving under her, leaving her high and dry, but safe and sound. Nothing can stop the oncoming pack except the land itself or a change of wind or tide. Sometimes the pack moves onwards even in fine weather; this means that there has been wind not very far off which has set the distant pack moving, its motion being transmitted to the entire body of ice.

With the lulling of wind comes a change. The ice which has been forced together opens up, lanes of calm water appear and smaller channels, till every piece of ice is more or less separated from its neighbour. The scene is altogether changed. As the white ice floats in the clear blue waters, one can scarcely realise that these same elements were not long since playing such a very different rôle. Now all this loose pack will with the advent of cold wintry weather be frozen together, the lanes of water will be

covered once more with young or bay ice. Wind and weather may pack it closer together, the plastic new ice giving way with the old ice embedded in its matrix. The whole becomes a solid floe, and many floes unite and form great "fields" of ice. This field ice is more formidable than the fields and floes of new ice that are formed during a single winter, and which during the following summer are known by polar voyagers as "one-year ice." At the beginning of winter they may show a thickness of possibly five or perhaps ten feet, and in places there will be even thicker pieces. Then comes a whole winter's intense frost, snow falls and adds to the weight and thickness, and when this ice breaks up the following spring we have a really formidable pack to encounter. When such pack ice is not very open, but still open enough for a protected ship to work its way through, the ship has to be handled with the greatest care even when navigating through it in fine weather. This ice cannot be charged indiscriminately like one-year ice, and one must be able to distinguish between one piece of ice and another. This can only be done by one who has had many years of experience of polar ice-navigation.

One piece, a heavy-looking mass, may be charged and will be shattered; another, a wise ice-master will avoid charging because

he knows it is of steely hardness and that his ship will make no impression upon it. A careful ice-master never touches a piece of ice if he can avoid doing so at any time, in spite of his stout ship, the full strength and power of which is needed when he is forced to work his way through tight ice and heavy ice, through which a novice would never dream a ship could pass. A good ice-master will nose his ship through ice that would seem to one without experience navigating amongst it absolutely impenetrable, and he will go through narrow lanes that are not as broad as the beam of his ship, first getting the starboard bow of the ship against an obstinate heavy piece and working it away in among its fellows and then pushing another piece similarly aside with the port bow. Then the ship is brought to a standstill with the engines going full speed, till bit by bit one sees a heavy floe beginning to rotate, and finally, by its motion and momentum, clearing a way, through which the good ship steams ahead. Now possibly comes a difficult place: two heavy floes have met at two points and there is open water beyond; screwing the ship is of no avail, the engines are stopped and reversed when the order of " go astern " is given. Then she charges full speed at the "neck of ice," and when the shock comes trembles from stem to stern, the mast and

yards shake violently and the crew are almost thrown off their feet, but there is no visible effect on the ice. This operation is repeated a second and a third time, and the narrow neck of ice between the two floes shows signs of cracking. Once more astern! Once more full speed ahead! The ice shivers, the neck breaks, and the gallant ship is in the open water that she has fought so hard to reach.

But it may happen that the task is hopeless, that too much valuable coal would be spent to accomplish the breaking of such a neck between two floes, and in that case the ship retreats and goes round the end of the floe instead. Or, if that seems of no avail, the ice-anchor is dropped over the ship's bows and she is made fast to the floe. There she waits, the skipper takes a meal and perhaps a sleep while his trusted mates watch developments. A change of tide or wind, perhaps three or four hours later or perhaps twenty-four hours later, causes the ice to slacken, and, without any effort, the ship steams through what was only a short time before an impenetrable part of the pack. Long experience of ice, good judgment, coolheadedness, and indomitable patience are the leading qualities of a good ice-navigator.

In the Arctic Regions the floes and pack ice are essentially the same as in the Antarctic Regions, except that there is more

snow on the floes, and consequently also on the pack, in the Antarctic Regions. In the Arctic Regions the snow on the floes is not only less, but is more consolidated and firm enough to walk upon; the snow is often very soft on the Antarctic floes. In the summer of 1892 and 1893, when cruising in Erebus and Terror Gulf, I sank to my knees when walking on the floes or pack, and the sealers often had hard work in dragging the skins of the slaughtered seals to the water's edge. The amount and softness of the snow doubtlessly varies in different years and different places, but there is, as a rule, more and softer snow on the floes in the south than in the north.

In summer it is warmer in the Arctic than the Antarctic, and the sun melts pools on the surface of the floes and pack. In this greater surface-melting the snow layer is diminished greatly during the summer months in the Arctic. I never met with pools of water on Antarctic pack ice, though such may occur. These pools of water on the ice in the Arctic Regions are in most cases composed of fresh water, so much so that when there is a considerable pool conveniently situated a whaler or exploring ship will fasten the ship on to the piece of pack or floe with her ice-anchors, and will, by means of the hose and pump, or by buckets, fill up the fresh-water tanks.

This water makes perfect drinking water, far finer than can be got in any seaport. To know that there is always in readiness a perfect supply of the most excellent fresh water is one of the greatest boons to ships navigating in the Arctic Regions, and a luxury which is forbidden to ships navigating in other seas. In the Antarctic, since one seldom or never meets with such pools, one has to pick out a nice old hummocky piece of sea ice or a bergy bit that has been chipped off one of the great bergs, and take some boat-loads of this ice on board. The ice is put into large tubs or barrels, and steam is blown through. It rapidly melts, and is led away into the ship's tanks and makes most excellent water. There is no excuse for a ship having bad drinking water on board in the Polar Regions. Through the entire winter in Franz Josef Land in 1896 and 1897, at our encampment at Cape Flora, we had a huge barrel inside the house not far off from the stove. Every morning after breakfast, it was regularly filled with compact blocks of consolidated snow that were quarried out of neighbouring gullies. This snow kept melting all day and night, and there was thus a constant supply of good water available. But during the wintering of the Scottish National Antarctic Expedition, when the *Scotia* was frozen in Scotia Bay for eight months, sea ice was

used for this purpose. A good old hummocky piece of ice would be selected by an officer, and then at seven o'clock every morning all hands would man two or three sledges, taking with them picks and ice-drills, and would bring several loads of beautifully clear blocks of ice back to the *Scotia.* A pile of this was made in a secure place on deck, and a large copper cauldron in the galley was continuously kept full of beautifully pure fresh water from the melting of this ice.

Be it specially noted that during the whole of this time we used sea ice for drinking, cooking and washing, and that fresh water was obtained from it with not the slightest taste of salt. The water was like "soft water"; when mixed with soap it made a good lather. Though it is interesting to note that when a delicate chemical test was performed with nitrate of silver, a slightly milky appearance showed itself in the water, demonstrating that there was actually an infinitely small amount of salt present, this was quite insufficient to be detected by taste. One very good criterion of the purity of this water was that it made excellent tea, and if anything is absolutely spoilt by the presence of salt, the subtle flavour of good tea suffers first. The absence of salt in ice that is formed from the freezing of salt water has been the subject of long and most important investigations

by Mr. J. Y. Buchanan (*Ice and its Natural History*, Royal Institution, May 8, 1908), who has established that the crystals formed in freezing a non-saturated saline solution are pure ice, the salt from which they cannot be freed belonging to the adhering brine, and that the freezing-point of water is lowered by the presence of salt or other foreign matter dissolved in it. Thus it may be said that, in nature, ice never melts and water never freezes at exactly 32° F. The melting-point depends on the medium and on the pressure to which the ice is subjected. If the pressure is constant it varies with the nature of the medium; if the nature of the medium is constant it varies with the pressure.

The reader is now able to distinguish the different species of ice met with in polar seas. The chief fact to be noted is that, in these seas, we meet with two kinds of ice, the one having its origin in the sea and the other on the land or in the air. The former has the lower melting-point of the two and melts first. While it is melting it takes all the heat available and so preserves the fresh-water ice, which melts after all the salt water ice is gone. In old hummocky ice this process of purification has been going on intermittently whenever the weather was warm enough. I trust I have made these matters plain, but it is impossible by words to give a

true idea of the marvellous colour and beauty of the ice in polar seas, or of its irresistible power when driven hither and thither by sea and wind. There can be no more terrific experience than a storm in a living polar pack. No human power is of any avail in resisting the combined onslaught of wind, sea, and heavy ice.

Yet I know no scene more wonderful and more stimulating than one of those brilliant sunny days in fine weather in the pack either in the north or the south. The dazzling ice shines like brilliants in the sun. Seals and penguins on the ice bask in the sun or play around pieces of pack ice, in and out, and over and under "tongues," in the intensely clear and often intensely bright blue water. In the south small shrimplike creatures (*Euphausia*), and in the north the midget polar cod, can be seen darting about in and out of the honeycombed ice tongues projecting under water from almost every piece of pack ice, probably sustaining themselves on diatoms and other algæ that are there too, and which stain the pure ice with a rusty brown colour near the surface of the sea. Snowy petrels, cape pigeons, and Wilson's stormy petrel in the south, and ivory gulls, kittiwakes and burgomaster gulls in the north fly gaily in the blue sunlit sky, speckled with thin wisps and flakes of cirrus

clouds. Penguins in the south and guillemots and puffins in the north dart like torpedoes in the narrow lanes of water, only coming to the surface for a breath. Every living thing seems bright and gay, stimulated by the brilliant conditions of the weather, which seems to throw crispness and life into the very ice itself, and makes the saddest think that there is joy in living.

Then the scene changes, as the sun, skirting the horizon, paints the white ice world with colour, with tints that are absolutely beyond conception if you have not seen them, and that no Ruskin can describe. These beautiful scenes—so soft and so delicate—produce impressions that can never be obliterated; different altogether from the effect produced by the brilliant scene described above. Soothing—not stimulating! Making one think of the world as kind and gentle, recalling the past, picturing the future. Making one think what a lonely unit one is in this world; making one compassionate and sympathetic to one's fellow men.

The cold grey scene depresses the spirit. The air is motionless, the sea of oily glassiness, and a dull whitish grey mantle of fog or mist hides everything from view, except the ship's deck and a few pieces of white ice near by, resting in dull grey water, fading away indefinitely in the mist. It is a

time of inaction: there is no object to go in one direction or another: nothing can be seen ahead. Sometimes several days of this weather continue, causing forced inaction, and one feels as if the rest of one's life was to be spent in this cold grey mantle. But there is a thinning of the mist; a gleam of the hidden sun; and a fog-bow subtly spreads its fairy ring upon the evanescent mist, which folds itself up in rolls and vanishes, and once more there is a brilliant world of sparkling sunshine.

In the Antarctic Regions almost all the ice floating in the sea, whether land or sea ice, is covered at sea-level with a light wash of yellowish brown or yellow ochre. The bergs are coloured by it as well as the pack ice, where the ice is lapped by the sea. When a ship charges against a piece of one-year pack ice, the ice is easily broken and often breaks not only vertically, but horizontally. The horizontal fracture occurs at about sea-level, and there is revealed a continuous layer of this ochreous ice. On examination it is found that the coloration is due to the presence of several species of diatoms, all actively living.

If the reader recalls the colour of a polar bear, he will know that the colour of its coat is yellow and not white. The coat varies, in fact, from being very nearly white at the end of winter and early spring when it is in

its finest condition. The bear-hunters well know this, several times the price being obtained for a winter skin than for one at the end of summer, when it is actually brownish yellow. This yellowness is more marked when the bear is in his natural surroundings of white ice, and at first sight seems anything but a protective coloration. Yet when an old Arctic voyager shouts "A bear!" younger hands will look a while before they see the heavy monster a couple of hundred yards off on a floe, and it is not easy, at first, to account for this, until looking across the great expanse of white one sights another bear, and keeps on seeing imaginary bears for a long time. The old veteran smiles and simply says, "Yellow ice." Then the novice easily accounts for his wrong conclusion, and finds that there are patches of yellow ice all over the floe just the colour of a polar bear's coat, lighter in spring when daylight has just returned and when winter snows and frosts still hold, darker in summer like the bear's dirty summer coat. I remember an incident on board the *Windward* in 1896, in the Barents Sea. All hands were on the poop deck on a Sunday afternoon while the veteran mate was conducting a short service. Short as the service was, our mate appeared unduly anxious to get it over, until, with a final effort, he finished—for-ever-and-ever-Amen-there's-a-bear! The

old boy had seen the bear shortly after the beginning of the reading till the animal was within a hundred yards of a congregation of twenty-five men, whose eyes, it must be confessed, wandered from the reader more than once, but not one of whom had seen the bear though he was in full view. The change of scene need not be described in this place, but before the bear was within thirty yards of the ship, he lay a victim to the devout mate and his congregation. Yellow ice was the explanation!

Now if some of this ice be collected and melted, a yellowish deposit is left, which on microscopic examination is found to be composed mainly of diatoms. These diatoms and other algæ spread themselves over the entire surface of Arctic sea ice, and the yellow patches indicate specially favourable growing-places for them. The distribution of these Arctic diatoms is somewhat different from that of those on the Antarctic ice. In the Arctic they are more on the surface, while in the Antarctic they are confined more or less to a thin lamina at sea-level, above which lies the remnant of the winter snow. In fact, the diatoms of Arctic ice are altogether different species from those of Antarctic ice. And while diatoms have nothing to do with bears, it is quaint to notice that in the Arctic Regions the yellow ice patches hide the polar bear from

vision; in the Antarctic Regions, where the yellow diatom material is, as a rule, covered with white snow, there are no bears to benefit by being lost among yellowish patches of their own colour. Later on I will say more about bears: just now let us remember their wonderful resemblance to the yellow diatom patches on the Arctic floes.

The diatoms of the Arctic floes and pack ice are also otherwise interesting. Certain species and varieties of diatoms found on the Greenland pack, which drives southward down the east coast of Greenland, are identical to those found near Behring Strait, and this was one of the reasons that made Nansen confident that the *Fram* would drift across the polar basin from the Siberian Islands to the Greenland Sea.

Now all these diatoms that have been referred to are distinctly associated with sea-water ice, and according to Cleve the Arctic ones "take their origin from salt water," and not from the land. In Antarctic ice the diatoms are all marine forms; but they probably live in the sea water permeating the ice in the lamina, which occurs in the pieces of pack ice at sea-level, below the surface snow, since those floating freely in the Antarctic seas appear to be different species from those found in this lamina.

On the surface of the sea, in all parts of

the world, diatoms and other algæ occur, and sometimes in such dense masses as to colour the sea. Scoresby (*Arctic Regions*, i, p. 176) noted that in the Greenland Sea the colour of the water was in places nearly grass-green. In the North Atlantic Ocean, in the spring of 1893, I saw bands of brilliant emerald green, like green meadows stretching for miles over the otherwise bright blue sea. And in the South Atlantic the *Scotia* passed through similar bands of a bright orange colour. These orange bands were fully thirty feet wide, and stretched several miles in length, and Dr. Rudmose Brown found they were composed of a gelatinous scum consisting chiefly of microscopic algæ (*Trichodesmium*) closely allied to diatoms. It is interesting to note that in this scum were numbers of Portuguese men-of-war, jelly-fish, swimming-bells, and crustaceans, and many other forms of animal life.

I make special mention of these remarkable occurrences because it is quite plain that all these animals were there dependent directly or indirectly on these unicellular algæ; some of the animals were feeding on the algæ themselves, others were preying on those very animals which had become luscious with the good pasture they had fed upon, and these in their turn were devoured by their larger and more rapacious brethren. Why the diatoms

were there is a more puzzling question, but there must have been sufficient nitrogenous and other food material to make them thrive so well—possibly the excreta or rotting carcase of a whale!

Now in the Antarctic seas, especially during my cruise in 1892 and 1893, I have recorded in my diary day after day such entries as these: "sea dirty green"; "sea dirty brown"; "sea dirty olive-brown"; "brownish green sea"; "olive-brown sea"; "sea green"; "water olive-green colour," and so on. When the silk tow-net was put over, it was quickly filled with a gelatinous mass, which adhered persistently to the silk, and which, even after thorough washing, blocked up the fine meshes, which could not be washed clear of it. On examination I found this slimy mass to be composed of *Corethron cryophyllum* and other diatoms.

Like the yellow bands of algæ in the South Atlantic Ocean, the immense quantity of diatoms and other algæ floating in the polar seas doubtlessly forms the basis of the enormous abundance of animal life there, from the small copepods and euphausia to the innumerable birds, seals, and giant whales. The nature of this discoloration of Arctic waters was shown by the late Dr. Robert Brown (*Transactions, Botanical Society, Edinburgh*, vol. ix, 1867) to be due to the presence of

enormous numbers of diatoms, among which lives a wealth of animal life, including medusoids, small crustaceans, and especially "winged" gastropods (*Clio*). There are such quantities of these diatoms that their siliceous skeletons, which are of a most indestructible character, form a great ring of deposit known as diatom ooze at the bottom of the deep southern ocean, all round the South Polar Regions. Deep-sea deposits will be considered in due course, but at present I wish to call attention to a remarkable fact, namely, that the distribution of the diatoms on the surface is different from their distribution on the bottom. The maximum occurrence of diatoms in the surface waters is south of 60° S., whereas the maximum occurrence of diatoms at the bottom is in about 51° and 52° S. This is doubtless due to strong undercurrents running in a northerly direction, which carry the delicate skeletons northwards as they sink downwards towards the depths. This rain of diatom ooze must form food for minute forms of animal life, which in their turn fall a prey to larger animals living in intermediate and great depths.

The diatoms of the Polar Regions, however, are not all marine forms. I have examined hundreds of land forms in the Arctic Regions, especially during my wintering in 1896 and 1897 in Franz Josef Land. Doubtless, also; there are species of diatoms that belong to

Antarctic lands. "On several occasions, notably on December 18th and 20th, 1892, I saw bergs which were fringed with pale brown streaks, like a vein apparently sandwiched in their main mass," and I believe that this coloration was due to diatoms or some other forms of algæ. This observation refers to tops of bergs that were possibly 150 feet above sea-level, and which had not been overturned. The tops being inaccessible, it was impossible to get a specimen. But I have seen similar coloration on land ice in the north.

One of the most remarkable instances of coloration of ice and snow on the land is what is known as "red snow," which is due to a blood-red microscopic alga known as *Sphærella nivalis.* I have seen acres of ice and snow red with this alga in Prince Charles Foreland, and other parts of Spitsbergen, as well as in Novaya Zemlya and Franz Josef Land, and on one occasion we found small patches at Scotia Bay in the South Orkneys. I have not seen it on other Antarctic lands I have visited, and am not aware that other explorers, except Dr. Charcot, who saw it in Western Graham Land, and Mr. Priestly, have recorded its presence. Mr. James Murray, who accompanied Sir Ernest Shackleton, writes to me saying: "I never saw red snow, but our geologist, Priestly, saw the snow smeared with red (some 30 or 40

miles from our camp). He collected some, but abandoned his specimens while saving his life after being carried away on a floe. In a lake close by was our now familiar red rotifer, and he suspected it caused the red snow. Certainly it could do so, if the water swarming with rotifers were blown out over the snow during a gale; they would not be killed by the cold. I find that Agassiz's red snow from the Alps contained red rotifers, probably the same kind." Lagerheim also reported finding rotifers in red snow in Nicaragua. It is quite clear, however, that it does not occur so frequently in the south as it does in the north, probably mainly owing to the higher summer temperatures that occur in the north. The red snow alga is not confined to ice and snow, and I do not consider that ice and snow is its chief habitat. Mr. George Murray, late of the British Museum, told me that he had known of this alga in the cistern of a London house. If one examines the dried-up shallow ponds and pools scattered all over Arctic lands in the late summer, when their water supply fails owing to lack of melting snow, one often finds the whole bottom of such ponds covered with a dark reddish-brown scum, which dries up into a sort of skin, covering all the ground and wrapping itself round every stone. On examination this is found to be composed

mainly of *Sphærella nivalis.* This red scum appears to thrive especially where such pools have been enriched in nitrogenous matter by water which has run down the rocks and taluses where great numbers of birds resort for nesting. It is often found that a glacier or snow-patch is coloured red when water flows over it from rocks where birds are nesting, and the well-known Scottish Arctic explorer Lamont, who has so ably depicted many an Arctic scene and incident, has ascribed the colour as being due to the droppings of the rotge; or little auk, which are, as he points out, of blood-red colour. But I have examined such patches of red snow and ice microscopically, and have found the redness due to the presence of the red snow alga. It is certain, however, that the droppings of the rotge will so enrich the water with nitrates that the red alga, which is growing plentifully, though invisibly, on the black rocks and ground, thrives exceedingly and is carried, and lives and grows on the melting surface of the snow or glacier ice. I have seen glaciers coloured green and black as well as red. The green colour is certainly due to green algæ, and the black, in certain cases, I have found to be due to fragments of desiccated lichen, fragments which do not appear to be growing on the ice but are there just as any other dust might be.

From this it will be seen that sea ice especially, and even the surface of glacier ice is swarming with life, and is by no means so sterile as it is usually thought to be. Bacteriological examination has demonstrated that the air of the Polar Regions is sterile, but under natural conditions in the Polar Regions, as in other regions, we may lay down a general law, and say—*Where there is water there is life!* It matters not whether this water be frozen with all the rigour of a polar winter, subjected even to over one hundred degrees of frost (F.). Melt this ice, whether fresh or salt, and life will be found. In Franz Josef Land I melted out solidly-frozen pieces of wet moss and soil, that had been subjected to a temperature of $-45°$ F. or 77 degrees of frost, and as soon as they were melted myriads of animals and plants began "to live, and move, and have their being," after a death-like winter sleep. Many algæ and even the mosses themselves continued life where they had suddenly stopped active living with the onrush of the winter frost. They had remained dormant during several winter months, and now active life suddenly began again. Innumerable wheel animalcules (Rotifera) and water-bears (Tardigrada) once more began to move and live, and in one case a small nematode worm that had evidently been on the point of laying its eggs when

overtaken by the frost months previously, began to lay them as soon as it had melted out, and continued its life as if nothing had happened during this long period of sleep. The researches of Mr. James Murray in the Antarctic Regions have since demonstrated the same phenomena, and he has further demonstrated that the Antarctic rotifers, after being frozen and melted, and then dried, can be subjected to the temperature of boiling water for a short time and yet continue to live.

The preservation of wooden crosses on old graves in Spitsbergen and other parts of the Arctic Regions as well as the remnants of wooden houses three centuries old, to say nothing of much of the driftwood which must have been left high and dry many centuries ago, is a striking piece of evidence of the sterility of the Arctic Regions from bacteria. The time will certainly come when a country like Spitsbergen and other parts of Polar Regions will be utilised as sanatoria, at least for the summer months. Concerning the bacterial sterility of the atmosphere, we have the striking facts that, under ordinary conditions, it is not possible to "catch cold" in Polar Regions, and that every germ disease is checked. A person who has a tendency to rheumatism in Britain or any similar country will not be attacked by rheumatism (unless possibly he is a very chronic rheumatic subject) in the Polar

Regions, though he may be night and day in a wet camp, continually soaked. It is possible to take a pleasant short sleep, if one is sufficiently tired, on soft slushy snow on a glacier in an exposed position and to be refreshed and to suffer no ill effects whatever despite a thorough soaking; you may get chilly, but you will not "catch cold," or get pneumonia and the like. Infectious fevers are practically unknown well within the Polar Regions, unless possibly contracted in a dirty ship or a filthily-kept house, and even then it is more than likely that no fever would be contracted during the winter months. Generally speaking we may say germ diseases are unknown well within the Polar Regions. People die of old age, organic troubles, such as various forms of heart disease, and by accident; not from germ diseases. Convalescents from serious illnesses rapidly recover, and get renewed health, such as they have never enjoyed before, and wounds heal effectively and with rapidity. Payer, speaking of Dr. Börgen's terrible wounds, says: "The first operation was upon the cabin table. And here we may briefly notice the singular fact that, although he had been carried more than 100 paces with his skull almost laid bare, at a temperature of −13° F., his scalp healed so perfectly that not a single portion was missing;" and Dr. Börgen himself says, "Nor during the process

of healing, which progressed favourably, did I experience the smallest pain" (*The German Arctic Expedition of* 1869–70, by Captain Koldeway, vol. ii, pp. 408 and 410). The darkness of winter is the chief enemy of man, as well as man himself. Provided a man lives a decently disciplined life there is no more healthy place in the world than the Polar Regions. It is the invariable experience of every well-organised polar expedition that the individuals increase in bodily health. Outside accidents, certain forms of heart disease have been about the only cause of death, and in these cases the trouble was probably present in its initial stages before the person joined the expedition, when it was difficult to detect, even by highly-skilled physicians; in such cases the patients probably could not have been saved from death even though they had never gone to the Polar Regions. It was stated, some years ago, that the death-rate of polar expeditions was less than that of the healthiest town in Britain, even including such disasters as the Franklin and Greely expeditions. Now, with better scientific organisation, the average death-rate has in all probability fallen much lower than this estimate.

CHAPTER V

PLANT LIFE

Besides bacteria and unicellular algæ there are other forms of plant life in the Polar Regions. Various forms of seaweeds, both large and small, were taken by the *Scotia* naturalists when dredging in shallow Antarctic waters. In Spitsbergen waters and in the Barents Sea, off Novaya Zemlya and Franz Josef Land, the Scottish expeditions have dredged up great quantities of different kinds of seaweed, especially laminaria, and after a storm on the west coast of Prince Charles Foreland I have seen piles of laminaria and other seaweed fully 5 or 6 feet in height, heaped up above the ordinary high-water level. This seaweed ultimately rotted on the shore or was driven inland by the wind. There is one remarkable feature of polar shores; and it is that, except in a few very secluded nooks and crannies, no seaweed will be found between high- and low-water mark, nor in depths of less than a fathom or two below low-water mark.

On examining the rocks on which one would expect this seaweed to grow one finds

that they are very much smoother and more rounded-off than the rocks on the shores of warmer seas. They are, in fact, quite polished. The reason is not far to seek, for to the depth of a fathom or so the sea becomes frozen solidly during the winter, and when summer comes and the pack breaks up, this and even heavier ice is driven along the shore and grinds over the rocks, rubbing and polishing them and preventing seaweed from growing there. Naturally also, for the same reason, one need not expect to find shore animals, and, as a matter of fact, shore fauna is very scanty in the Polar Regions. There may be a few limpets in a relatively deep crack, or a few amphipods and a stray fish, but there are few hiding-places for them among rocks so depleted of weeds. No sessile animal is safe from being crushed and scoured off the rocks by stranding ice. Even on a sandy shore there is little, though there is better chance here, especially if it does not shelve steeply. Worms, copepods, ostracods and the like may sometimes be found in abundance on a shallow sandy shore, especially if there is some bar or barrier which prevents heavy ice being stranded on the beach at high water during the short summer season.

On the land, plant life may be represented by more than diatoms and other algæ. But, be it noted, land plants have a better chance

and are far more numerous in the Arctic than in the Antarctic Regions. For whereas there are about 400 species of flowering plants in the Arctic Regions, until Dr. Charcot discovered two flowering plants in more than one locality on the western coast of Graham Land—a grass, *Aira antarctica*, and a small umbelliferous plant, *Colobanthus crassifolius* var. *brevifolius*—no flowering plant was known to exist in the Antarctic Regions with the exception of this grass, which was known to be a native of the South Shetlands. A considerable number of plants, however, occur on some subantarctic islands, such as Kerguelen, South Georgia, etc. Except these two flowering plants which I have mentioned not a single one has yet been found on any land in the vicinity of Antarctica or the islands immediately adjacent to that continent, not even in the South Orkneys. Though grass had been reported on these islands, we know now that it certainly does not exist.

The most likely reason for this absence of flowering plants is the short Antarctic summer with temperatures very much below those of the Arctic Regions. In the South Orkneys, for instance, in 60° 44′ S. the mean summer temperature of the three summer months (December, January, and February) is below freezing-point, viz. 31·7° F.; and in no month does the mean rise to 33° F.; at Snow Hill,

Graham Land (64° 24′ S.) the mean of January, the warmest month, is 30·38° F., while at Cape Adare, Victoria Land (71° 18′ S.), the summer mean is 30·4° F.

Comparing these summer temperatures with those of the Arctic Regions, it is found that in Spitsbergen (79° 53′ N.) the mean temperature of July (corresponding to January in the south) is as high as 41·50° F., and that in Franz Josef Land (80° N.), it is 35·6° F. in the same month. The mean temperature in Spitsbergen for June, July, and August is 37·1° F., and even that of the ice-bound King Oscar Land in 76° 40′ N., 88° 40′ W., is 33·35° F. The point is, that while the mean temperature of the summer months in the Arctic Regions is well above freezing-point, viz. 32° F., that of the Antarctic Regions is practically always below the freezing-point. "This remarkably cold Antarctic summer," says Dr. Rudmose Brown, "acts in two ways upon plant life: *firstly*, the winter snow lies late on the ground —all the later as the summer is a cloudy and somewhat sunless period, and December is well advanced before the majority of available sites are laid bare, while in February the winter again begins; *secondly*, and this is the chief reason, it is doubtful if a flowering plant could obtain the requisite amount of heat needed for its various life functions even to reach the flowering stage, while the maturation of its

fruit would be next to impossible" ("Antarctic Botany," by R. N. Rudmose Brown, Scottish National Antarctic Expedition: *Scottish Geographical Magazine*, 1906, vol. xxii, No. 9). Another very serious factor against plant life in the Antarctic Regions is the presence of enormous numbers of penguins on almost every available piece of ground on which plants could grow. It is only occasional out-of-the-way spots, not readily accessible to the sea, and so free from penguins, that are available for plant growth. On Mossman Peninsula, in Scotia Bay, there was one very favourable place, where about an acre of rocky ground was covered with 6 or 8 inches of moss and vegetable soil derived from the moss that had grown there for many a year. Such mossy grounds, however, are very late in losing their winter snow, so that if the seeds of flowering plants reached such a nidus they would have very little chance, even if they germinated, of securing a sufficiently firm foothold before the summer was gone. Owing to a prevalence of north-west winds, Dr. Rudmose Brown is of opinion that some wind-blown seeds of Fuegian plants may reach Graham Land, the South Shetlands, and the South Orkneys; but the absence of driftwood on these lands shows that there is much less chance of their reaching these lands, either by sea or ice, than there is in Arctic Regions,

where on most shores enormous quantities of driftwood are stranded year after year, so much so that some places have the appearance of timber yards.

The absence of land birds, with the solitary exception of the Sheath-bill (*Chionis*), is against the transit of seeds, though some petrels, the Dominican Black Back Gull, the skuas, and the shags may occasionally carry seeds to these lands.

As far as the geographical distribution of plants is concerned, Skottsberg and Rudmose Brown consider the parallel of 60° S. forms a more or less natural limit. (Note how difficult it is to give a hard and fast limit for the boundary of the Antarctic Regions: the astronomer takes the Antarctic Circle, the botanist the 60th parallel of south latitude, and the oceanographer the limits of floating ice.) "The flora of the Antarctic regions," says Dr. Rudmose Brown, "as thus defined, contains only two phanerogams, namely, *Aira antarctica* (Hook. Des.) and *Colobanthus crassifolius* (Hook. f. var. *brevifolius*, Eng.). The former of these has long been known from Antarctic Regions, having been collected by Eights about 1820 at the South Shetlands, and it also occurs on Danco Land, but its discovery along with *Colobanthus crassifolius*, by Dr. Turquet, of the French Antarctic Expedition at Biscoe Bay, Anvers Island, in 64° 50′ S.,

68° 40′ W., is very interesting, for this is the most southerly record for flowering plants known. *Descampsia antarctica* was also found by Dr. Turquet at Booth-Wandel Island, 65° 5′ S. It is extremely probable that further exploration will somewhat extend the range of these species." In 1910 Dr. Charcot's expedition in the *Pourquoi Pas?* found these two flowering plants as far south as 68° S. "Ferns are entirely wanting in the Antarctic, as was only to be supposed, but mosses are relatively abundant, and form almost the chief constituent of the flora. Collections of these are known from various points around the pole, including Graham Land, South Shetlands, South Orkneys, Wilhelm Land and Victoria Land, but those from the Atlantic and American sides are incontestably the richer, no doubt largely because of the nearer proximity of extra-polar land and consequent possibility of migration, but also to some extent because that side of the Antarctic regions has received more careful and serious exploration than any other." Dr. Jules Cardot, who has examined the mosses brought back by all the recent expeditions, places the total number of species at present known at about 51. Nearly 50 per cent. are endemic, while about 23 per cent. are found in Arctic Regions as well, but the majority of these are of more or less cosmopolitan distribution.

Only six Antarctic hepatics are known, and only one fungus discovered by M. Racovitza of the *Belgica.*

Lichens predominate though more numerous as individuals than species. Various orange-coloured species of *Placodium* even show well-marked coloration on precipitous rocks in winter. The grey and shaggy *Usnea melaxantha,* Ach., is more luxuriant than any other and produces good "fruits." All but one of the South Orkney lichens collected by Dr. Rudmose Brown of the *Scotia* have been previously recorded from the Arctic Regions. Altogether about 75 per cent. of the Antarctic species are also Arctic forms. Twenty-five species of marine algæ, including five new species, were taken by the Scottish Expedition in South Orkney waters. Of diatoms I have already spoken. Fresh-water algæ are almost confined to unicellular kinds, but had been little studied until Mr. James Murray found "abundance of fresh-water algæ, including some very small diatoms, in ponds, and also in earthy deposits, which may have originated in ponds."

This is a brief summary of all that is known regarding the Antarctic flora. It is quite impossible to enter into similar detail regarding the Arctic flora on account not only of its profusion, as already indicated by the number of flowering plants, but also because

of the enormous amount of investigation that has been carried out by very many eminent botanists from every civilised nation. The literature of Arctic botany fills many shelves. In so much detail has Arctic flora been investigated, that it is quite a rare thing to record a new species, and even regarding distribution there is little more to be learnt. The present interest is the study of the physiology of Arctic plants, and here a beginning has already been made. Under these circumstances it is neither necessary nor desirable to enumerate even in the most general way species of Arctic plants nor to discuss their distribution more than I have done already in the case of the diatoms of the Arctic seas and floes.

But plant life in Arctic lands is a feature of such importance that it must not be passed by without giving some consideration to it in a general way. One striking feature is, that no matter how far north the explorer goes, no matter how desolate a region he visits, he is sure to come across one or more species of flowering plants. A poppy, buttercup, or saxifrage is almost certain to be met with, and of all these the Arctic poppy (*Papaver radicatum*) is perhaps the most persistent. There is no place that I have visited in Spitsbergen, Franz Josef Land, Novaya Zemlya, or elsewhere, however barren, desolate, and windswept, where I have not found the Arctic

poppy growing, stunted it may be, yet growing and even flowering; and, if there exist in the least degree slightly more favourable conditions, it will grow with great luxuriance and in great profusion. Similarly, on the coasts of Greenland and on the Arctic islands north of America wherever plant life can succeed the poppy is to be found. Next to the poppy, the purple saxifrage (*Saxifraga oppositifolia*) is probably the most hardy Arctic flowering plant, and in suitable places may grow in even greater profusion than the poppy. I have seen the Foreland Laichs of Prince Charles Foreland in July resembling an extensive Scottish moor in September, one blaze of purple for miles, but purple with this saxifrage instead of with heather. A yellow buttercup (*Ranunculus nivalis*) is another very common Arctic species growing almost anywhere, and very different in appearance according to what ground it is growing on, and to what extent it is protected from wind. *Cerastium alpinum* is also met with everywhere, great masses of white brightening the landscapes. Other flowering plants that every Arctic traveller is thoroughly familiar with are: scurvy-grass (*Cochlearia officinalis*), the sulphur-flowered buttercup (*Ranunculus sulphureus*), the little bladder campion (*Silene acaulis*), several potentillas (*P. nivea, P. pulchella*, and others), the blaeberry (*Empetrum nigrum*),

many saxifrages, notably *Saxifraga cernua, S. cæspitosa, S. Hirculus*, the rock rose (*Dryas octopetala*), the cotton grass (*Eriophorum*), and last, but not of least importance, the Arctic willow (*Salix polaris* and *S. herbacea*), which often covers acres of ground. Neither must we forget the great host of grasses and sedges. Few of these plants are endemic to Arctic Regions; they often develop characteristic forms or varieties, but most of the species are found also in northern Europe, Asia, and America. Further south they appear at higher altitudes. A few we find on the hill-tops of Scotland. There are two ferns in Spitsbergen and a few more in other Arctic lands, but the Arctic Regions are not favourable to fern growth. Of mosses and hepatics there are many different species, most of which thrive exceedingly well, and the same may be said of lichens. Fungi are also quite common, especially puff-balls, with their "Deadman's snuff." One common feature that Arctic and Antarctic mosses and lichens exhibit is the infrequency of any reproduction except by purely vegetative means; by growth, in fact, continuous or discontinuous, for as a rule they are barren: "fruits" in a state of maturity are comparatively rare.

Although there are many barren stretches in Arctic lands, especially those regions that are open, exposed, and wind-blown, yet even

on such places stunted desert-like tufts of some of the commoner species will be found, especially the Arctic poppy and purple saxifrage. These were growing on a narrow strip of ground only a few yards long, and at the most four or five yards in breadth, on an island in Franz Josef Land, north of the 80th degree of latitude, that was otherwise completely covered with permanent ice and snow. I have also found these plants growing on the tops of the mountains of Spitsbergen north of the 79th degree of latitude, at an altitude of more than 3,000 feet—as bleak exposed places as any on the face of the globe. Give these plants the least bit of fair play as regards environment—a sheltered glen, or the shores of a loch or firth, where there is sufficient moisture, plenty of sun, and good soil enriched by the water running down from the wonderful bird cliffs inhabited by hundreds of thousands if not millions of birds, or by the droppings of reindeer, musk-oxen, and other animals, and a veritable paradise of verdure is produced. I have basked in the sun on wide stretches of the purple saxifrage, and have wandered over meadows green with the Arctic willow, and many different species of saxifrage and mosses ; I have waded through grass and sulphur-flowered buttercups up to the knee and plunged my hands deep into velvet banks of rich green and red mosses, while my eyes have

feasted on a brilliant display of green, white, gold, and purple. Other Arctic explorers have had the same experiences—Scoresby, in Jameson's Land (71° N.) on the east coast of Greenland, says, "the ground was richly dotted with grass, a foot in height," and, he continues, "more inland, my father, who explored this country to a great extent, discovered considerable tracts that might justly be denominated *greenland*, patches of several acres, occurring here and there of as fine meadow-land as could be seen in England. There was a considerable variety of grasses and many other plants in a beautiful state" (*Journal of a Greenland Voyage*, by Wm. Scoresby, junior, F.R.S.E., 1823, p. 214). In Grinnell Land (79° N.) in 1875 the British Arctic expedition met with "luxuriant vegetation," and in 82° 30′ N. Captain Markham (*The Great Frozen Sea*) says, "Some of the hills surrounding these lakes were beautifully carpeted with the pretty little purple saxifrage, a *Draba*, a *Potentilla* and other wild flowers, while the valleys were covered with patches of luxuriant vegetation, consisting of grasses and delightfully soft moss." Speaking of the island of Waigatz, Colonel Feilden says, "Nowhere in the Arctic Regions have I seen such wonderful masses of colour; one may wade through acres of blossoming plants a foot high, veritable Arctic flower-gardens. . . . My words fail, I know, to give any adequate

description of the immense charm attaching to this Arctic flora" ("Visits to Barents and Kara Seas, with Rambles in Novaya Zemlya, 1895 and 1897," by Colonel H. W. Feilden, *Geog. Journal*, April 1898). Again, Conway says, "A veritable Arctic garden surrounded the tents, for the ground was gay with blossom. There were large patches of *Saxifraga oppositifolia* scattered about like crimson rugs. *Dryas octopetala* and the Arctic poppy were as common as buttercups and daisies in a meadow. Yellow potentillas (*P. verna* and *multifida*) added their welcome note of bright colour. The Alpine *Cerastium* was the gracefullest blossom of the company. Then there were two *Drabas*, a *Silene*, *Melandryum apetalum*, *Oxyria reniformis*, and a number of other plants not yet in flower, besides the mosses. It was strange to meet again in this remote region so many plants that I had found by the glaciers and amongst the crags of the Karakoram-Himalaya. *Papaver nudicaule*, *Saxifraga oppositifolia* and *Saxifraga Hirculus* climb to a height of 17,000 feet and more on the sides of the greatest giants of that most wonderful range. Here they all were again, as bright, and maintaining themselves as happily in the heart of the Arctic Regions as on the backbone of Asia" (*The First Crossing of Spitsbergen*, by Sir W. Martin Conway, 1897, p. 125). Such quotations could

be almost infinitely multiplied, for every Arctic voyager has been similarly fascinated with the wonderful luxuriance and beauty of the Arctic flora.

But besides being a fascinating feature of Arctic scenery, vegetation on Arctic lands has played and will continue to play a most important rôle in Arctic exploration. Without it the North Polar Regions could not have been penetrated so extensively as they have been by man, and, if greater advantage had been taken of it directly or indirectly there would not have occurred some of the disasters that have marred Polar exploration. As long ago as 1671 Martens knew the value of sorrel and scurvy-grass in Spitsbergen for human food. "I desire," says Martens, "the courteous Reader to accept at present of these for Sample to shew him that on these rough, barren, and cold Mountains, there yet grow some Plants, for the Nourishment both of Man and Beast. The Herbs grow to their perfection in a short time, for in June, when we first arrived in Spitsbergen, we saw but very little Green, and yet in July most of them were in flower, and some of them had their Seeds already ripe, whence we observe the length of their summer." It is a striking fact, although it was recognised two and a half centuries ago that Arctic plants afforded "Nourishment both for Man and Beast," that more advantage

was not taken of them and of the "Beasts" this rich vegetation also sustained. Without this rich Arctic vegetation from lichens onwards there could be no musk-oxen, no reindeer, no Arctic hares, no lemmings, no owls, no ptarmigan, no geese, fewer ducks, no purple sandpipers, stints, sanderlings, buntings or any other land birds, few insects, and a scarcity of other invertebrates.

With all these animals, which will be considered in more detail later on, Arctic lands become habitable for the various tribes of Eskimos that live and thrive there, and European races have been able to penetrate parts that could not otherwise have been reached with means that have been at our disposal up to the present time. Without these animals the Arctic tundra of Europe, Asia, and America could not have been crossed and opened up so thoroughly, the coast of Greenland could not have been explored except in the most meagre way, and the great Archipelago of islands—great and small, that stretches towards the Pole to the north of our Canadian Dominion—could not have been investigated as it has been.

But not only does all this magnificent supply of fresh food from Arctic land animals depend on the luxuriant vegetation there, but some of the plants are actually adjuncts to the food supply, notably scurvy-grass and sorrel, both

of which are pleasant and healthy vegetables, and both of which help to ward off scurvy. Lichens have even been used as food for men crossing barren wastes where hardly any other plant existed, and when animals were not there to be hunted or difficult to secure. Franklin, Richardson, and Back maintained life by eating "an old pair of leather trousers, a gun cover, a pair of old shoes with a little '*tripe de roche*' that they succeeded in scraping off the rocks."

The success of Polar expeditions depends not only on selecting a good set of healthy men, but also, once the expedition is in the field, on maintaining that good health and even on improving it. Scurvy has been the deadliest enemy of Polar expeditions, whether they have been for hunting or for exploration. Spitsbergen and other Arctic lands are one huge cemetery containing the remains of scurvy-stricken men and women who have died through ignorance and obstinacy, and even within the last few years many hunters have died because they have preferred to eat badly-cured fish and badly-prepared animal foods, instead of feeding on the food that the Almighty had placed at the very doors of their miserable and filthy huts.

Half the members of the British Polar Expedition of 1875–76 were saturated with scurvy, and expeditions as late as those of the

Balæna (Weddell Sea, Antarctic), 1892–93, *Windward* (Franz Josef Land, Arctic), 1894–97, and the *Discovery* (Ross Sea, Antarctic), 1901–4, were all seriously crippled with the appearance of that terrible scourge. On shore at Cape Flora Dr. Reginald Kœttlitz was able to prevent scurvy because the leader and staff followed his advice and lived chiefly on bear meat and guillemots, but, as Dr. Neal has pointed out, nearly all the men on board the *Windward* "refused to eat bear meat, but lived on tinned provisions, with plenty of tinned vegetables and any amount of lime-juice. The whole ship's company, except three or four men, had scurvy, and those who did not have scurvy were the very ones who took bear's meat whenever they could get it. The ship arrived in Norway in September 1895, having lost three men from scurvy, and with fourteen others who would have been dead in a few days if they had not reached land."

For many a year lime-juice has been used as a preventive and cure, but doubtlessly the best that can be said of it is that it will do no harm using it in cases of scurvy, and it may or may not be useful in other directions. On board the *Balæna* one ounce of lime-juice was regularly served, "according to the act," every day to every man on board, and yet, on the return voyage to Britain, one and all

were more or less tainted with scurvy, including one seaman who was very seriously ill, and who was receiving fully two ounces of lime-juice a day. The *Balœna*, flying the yellow flag, put in at Portland for coal and potatoes, and apparently the potatoes, which were ravenously devoured by the crew in the raw state when they came on board, and which were afterwards copiously served out boiled, had the wonderful effect of largely obliterating the scurvy before the vessel reached Dundee four days later. While as to the seaman who was utterly prostrated, and who was so ill that he was expected to die any day, he so far recovered as to be able to walk ashore in Dundee. At the same time the Norwegian ship *Jason*, that did exactly the same voyage as the *Balœna*, had no lime-juice on board, and had not the least trace of any scorbutic symptoms.

Dr. William H. Neale, who spent the winter of 1881–82 with Mr. Leigh Smith in Franz Josef Land, in *The Practitioner* for June 1896, describes how, though the wrecked party "had practically nothing to live upon but bear and walrus meat for twelve months, there was not a drop of lime-juice saved from the ship; and the vegetables were so few that they could not be taken into account." Dr. Neale continues, "My belief is that our complete freedom from scurvy was due to our

living in a pure atmosphere night and day, and our diet being mainly fresh meat with plenty of blood in it. . . . Give me a hut on shore and a rifle with easy access of game, and I would defy scurvy in the Arctic Regions; but to live on board a ship, to live in a hot forecastle or cabin, and to live on tinned provisions, is the best means of courting the disease."

We know now, by careful physiological research and by further experience of well-equipped expeditions basing their food equipment on the results of our knowledge obtained by these investigations, that scurvy is largely, if not entirely, due to the presence of injurious ptomaines associated with animal food-stuffs, and it has been said by an eminent physiologist that it is simply a form of chronic ptomaine poisoning. A well-equipped Polar expedition, where the greatest possible care has been exercised by the leader, and honestly carried out by the contractors, should not, therefore, have scurvy on board or on shore at its encampments. It must be acknowledged, however, that it is very difficult to make absolutely sure that all the preserved meat-stuffs on board are reliable, especially as there are scandalous contractors, who care nothing for sacrificing the health, and even the lives, not only of those who penetrate the Polar Regions, but of those who journey to other

parts of the world, both in times of peace and war.

The great maxim to follow in Polar exploration as regard food supplies is to live as far as possible on the products of the sea or land where the work of the expedition lies. If the expedition is exploring in the Antarctic Regions, let it feed on the excellent flesh of the seals and fish which can be got plentifully there, and on the eggs and flesh of the innumerable penguins and other birds. If the expedition is in the Arctic Regions, let it luxuriate in the flesh of the musk-ox, reindeer, hare, and ptarmigan; and let the meat of bear, walrus, seal, and guillemot, as well as other birds, be utilised, remembering that all this "flesh is grass," and let scurvy-grass and sorrel be eaten as the natural vegetables of the Polar Regions. Tinned foods, if risked at all, should be used merely as a variety apart from the staple fresh foods above mentioned. Then there will be no sign of scurvy.

CHAPTER VI

ANIMAL LIFE

Brief reference has already been made to some of the polar animals and their habits, but it is necessary to give a more detailed account of this aspect of Polar Regions. The striking feature of the Antarctic Regions, with one partial exception, is the entire absence of land vertebrates. There are no land mammals—no bears, wolves, foxes, or lemmings; no musk-oxen, reindeer, or hares, neither are there any land birds with the exception of the sheath-bill (*Chionis*), which is only a summer visitor to the shores of most Antarctic lands. Some white-legged sheath-bills, however, remained at Scotia Bay all the winter of 1903, and Sir Joseph Hooker tells me that the black-legged sheath-bill remains in Kerguelen all the winter. Neither are there any fresh-water fishes, as there are practically no rivers and only a few pools which are scarcely ever free of ice. This striking fact makes inland journeys in the Antarctic Regions very much more serious business than the inland journeys

in the Arctic Regions, since every pound of food required for a journey has to be carried by the explorers. There is no food in the interior of Antarctica. There is not a single living thing, except possibly a stray lichen or moss, which may harbour an insect or two, or some microscopical invertebrates and unicellular algæ.

In the Arctic Regions, on the other hand. with the perfect and light equipment that is carried nowadays and with the modern and accurate long-range firearms, so different from those used by Franklin, Rae, Richardson, Back, and others, who actually starved with reindeer in sight, there is little chance of explorers not being able to obtain food supplies. It is true there may be difficulty on occasions in obtaining food by one's own gun, in certain districts, for several days, but it is scarcely possible now to be reduced to such extremities as Arctic explorers were in the days of Franklin and Rae, with their heavy equipment and primitive firearms. Even as late as the Nares expedition of 1875, extraordinary "regulation" equipment was carried—great solid sledges, massive canteens, heavy ships' boats, etc., instead of light sledges, thin aluminium canteens, canvas kayaks, and the like, which are the Polar equipment of the present day. A modern Polar explorer marvels at the wonderful achievements of his predecessors, which are all the more remarkable when he

knows that, added to this cumbersome equipment, their preserved provisions were such as almost certainly to cripple their strength, if not utterly to prostrate them with that deadliest of Polar enemies—scurvy.

The most striking of all Polar animals is undoubtedly the Polar Bear (*Ursus maritimus*). The resemblance of this remarkable animal to its surroundings has already been dealt with; let us now consider other characteristics. The habitat of the bear is the sea ice and the sea, and not the land. The polar bear is constantly wandering about the floes and pack. It is a solitary animal usually. If there are two or three together, they will be a mother with one or two cubs. The bear does not hibernate, as is commonly supposed, but walks around in a desultory manner, examining and sniffing at everything. Dr. Kœttlitz has pointed out that what have been called hibernating holes or caves are only ice and snow houses constructed occasionally by the male and female for shelter in very bad weather, but usually by the female for shelter during her final stages of pregnancy and for a little time after the birth of her young. The mother and young do not appear to stay long in these caves, but soon begin again their wandering life. Their wanderings seem objectless except for the sake of obtaining food. The chief food of the polar bear is seals, preferably the floe-rat (*Phoca fœtida*).

A bear has been seen lying stretched on its belly at the edge of a floe, watching intently the water till a floe-rat coming to the surface has put his head out for a breath and look out: no sooner had the seal's head appeared than one fell stroke with the heavy paw of the bear landed its prey, stunned, on to the floe.

During the winter-time, when the sea gets more or less frozen up into one continuous field of ice, bears are constantly wandering about in the vicinity of cracks in the ice, or near the breathing-holes which the seals keep open all the winter by constantly coming in and out of them. It is very doubtful if a bear ever catches a seal sleeping; it is by long and patient waiting at a seal's hole, and by strategy and stalking that the seal falls a victim to the bear. The bear's skill as a stalker is well instanced by an incident that nearly deprived Nansen of his companion Johansen, during their journey from the *Fram* to Franz Josef Land across the Polar Basin. Before either of them or even their two dogs were aware of its presence, a bear had felled Johansen by his heavy paw. "The bear," says Nansen in his *Farthest North*, "must have followed our track like a cat, and, covered by ice-blocks, have slunk up while we were clearing the ice from the lane and had our backs to him. We could see by the trail how it had crept over a small ridge

just behind us under cover of a mound by Johansen's kayak. While the latter, without suspecting anything or looking round, went back and stooped down to pick up the hauling rope, he suddenly caught sight of an animal crouched up at the end of the kayak, but thought it was 'Suggen.'" Fancy taking a bear for a dog, a couple of yards off! Yet I know how possible this is, having myself at various times mistaken a dog, a gull, and a flag for a bear!—"Before he had time to realise that it was so big, he received a cuff on the ear which made him see fireworks, and then, as I mentioned before, over he went on his back. He tried to defend himself as best he could with his fists: with one hand he seized the throat of the animal, and held fast, clenching it with all his might. It was just as the bear was about to bite Johansen on the head that he uttered the memorable words, 'Look sharp!' The bear kept glancing at me continually, speculating, no doubt, as to what I was going to do; but then caught sight of the dog and turned towards it. Johansen let go as quick as thought and wriggled himself away, while the bear gave Suggen a cuff which made him howl lustily, just as he does when we thrash him. Then Kaifas got a slap on the nose. Meanwhile Johansen had struggled to his legs, and when I fired had got his gun, which was sticking out of the kayak hole. The only harm done

was that the bear had scraped some grime off Johansen's right cheek, so that he has a white stripe on it, and had given him a slight wound on one hand; Kaifas has also got a scratch on his nose. Hardly had the bear fallen, before we saw two more peeping over a hummock a little way off—cubs who, naturally, wanted to see the result of the maternal chase. They were two large cubs."

I was once similarly stalked by a bear that watched its chance for a long time, while I was busy attending to some baited traps lowered in the sea, through a hole in the ice, three-quarters of a mile from the shore where the encampment was. Fortunately, by the vigilance of one of my comrades, Armitage, the bear was detected when within a hundred yards of his prey, and, finding he was discovered, made off. The remarkable swimming powers of the bear were exhibited well on this occasion, for he took to the water and began to swim towards an island that was twelve miles distant. A bear is, in fact, just as much at home in the water as on the ice, and often, if it comes to a large pool of water in the floe, a bear will swim across rather than take the extra trouble of walking round.

Although there have been many narrow escapes from polar bears, it is doubtful if there is any authentic record of a man being

killed by a bear. Dr. Börgen, of the German Polar Expedition in 1869–70, had perhaps one of the most marvellous escapes that has ever been recorded. Dr. Börgen was knocked down by a bear that seized him by the head in its jaws and carried him off. The bear and its victim were followed, and the bear ultimately shot. Dr. Börgen received a very severe scalp wound, as well as wounds on the arm and hand, from which, however, he soon miraculously recovered, as already stated. The bear seldom comes to the land as long as he can get plenty of seals on the sea ice; he will only come if he knows of a short cut across some land or glacier to get from one feeding-ground to another, or he will come to eat grass as a dog does when he is not feeling well. He may also come to land if there is a human encampment, being attracted by the smell; and this habit is so well known that hunters when ashore or on board a ship will burn seal or bear fat, and if there is a bear to leeward he is sure to come up to the encampment or ship. In this way about 120 bears were seen and 69 were shot in Franz Josef Land during 1894–97, by the Jackson-Harmsworth Expedition. When hungry, a bear will eat anything. Kœttlitz found seal, grass, seaweed, paper, manilla rope yarn, a hard lump of woven texture, horse-dung, macintosh sheeting, canvas, basaltic pebbles and bear

blubber in the stomachs of thirty bears he examined. But the bear's usual food is seal, and although he will devour every part of a seal, his particular fancy is the skin and blubber.

Of land mammals, musk-ox (*Ovibos moschatus*) and reindeer (*Rangifer tarandus*) are the most noteworthy and useful to man. The musk-ox is specially interesting, being the single representative of its genus. It is more nearly allied to the sheep than the ox. It is about two-thirds of the size of the American bison, but its long coat of hair makes it look larger. It inhabits the northern parts of the Canadian mainland, and the islands to the north of Canada as far as Grinnell Land, as well as the coasts of Greenland. In prehistoric or pleistocene times the musk-ox extended to the north-west in Alaska, and at a still earlier period, when North America was colder than now, the musk-ox ranged as far south as Kansas and Kentucky. Musk-ox bones have been also found in the frozen soil of Siberia, as far east as the Obi. It formerly existed as far south as Wurtemburg, while the Pyrenees and Alps seem to have marked the southern limits of its range. The skulls have been dredged up from the Dogger Bank. Unlike the bear, the musk-oxen keep in herds, and they are seldom met singly. "This herding gives them a better

chance to defend themselves against their one enemy, the arctic wolf." When danger is at hand they "always retreat," says Mr. Biederbeek, "to some elevation near by, and upon the approach of the enemy they form in a perfect line, their heads toward their foe; or if attacked, at more than one point, they form a circle, their glaring, blood-shot eyes restlessly watching the attack."

Like the bear, they are protected by their environment, as a description by Captain Otto Sverdrup shows (*New Land*, vol. i, p. 47). "As I was working my way past a sudden bend in the valley, I suddenly saw both animals standing high up on a steep crag, and within range. It was merely by chance that I caught sight of them, for the crag was exactly the same colour as the animals, and this was the only place in the valley of that particular tint. So the polar ox, I thought, seeks cover from the prevailing tone of his environment, just as does the ptarmigan from the stones and juniper in summer, and in autumn, after it has changed its colour, from the large patches of snow." "Musk-ox," says the late Dr. E. L. Moss (*Shores of the Polar Sea*), who has depicted so well many an Arctic scene by his pen and brush, "rarely attack, and can generally be approached within rifle-range with little trouble. Sometimes, however, they are unaccountably timid. . . . They

seemed to take some time to realise that we did not belong to their world. But having once made up their minds, they showed even more terror than wild animals usually do. Each musk-ox gave us about two hundred pounds of meat, often most excellent, but occasionally tainted with the flavour that gives them their name. We failed to ascertain the source of this characteristic. It occurs in both sexes and at all ages; and, moreover, it is not peculiar to the musk-ox, for a haunch of reindeer presented to us by the governor of Egedesmunde possessed the very same flavour."

The musk-ox has been a most valuable asset to polar explorers. Without its existence the north and east coasts of Greenland could not have been unravelled as they have been, nor could exploration have been carried on so effectually in the Canadian Arctic Archipelago.

The reindeer (*Rangifer tarandus*) is another not only striking but also useful Arctic animal, and one of the most widely distributed. Some consider there are two species, but that matters little just now; suffice it to say that the reindeer is found in almost every Arctic land, except Franz Josef Land, where however at one time it used to exist, since their horns have been found there by myself and others. Its range extends so far south on the European,

Asiatic, and American continents that it may be regarded as being not only an Arctic but also subarctic animal. The reindeer differs from all other deer in that both male and female have antlers, though those of the female are smaller. The genus is distinguished by the form and position of these appendages, which take their origin immediately over the occipital ridge instead of low down in the forehead. Another characteristic is the broad-spreading hoof, giving a good surface for support on snow or bog. The tail is conspicuously white. The larger varieties may weigh up to 400 lbs. The reindeer proves most valuable nutriment for Arctic explorers, and Eskimo, and other Arctic tribes; and, like the musk-ox, has constantly furthered Arctic exploration, not only as a valuable food supply, but also because its skin is one of the most useful articles of clothing. Reindeer-skin sleeping-sacks have been an almost indispensable part of the equipment of Arctic and Antarctic explorers; the skin of the young reindeer is suitable for various articles of clothing. The skin of the legs of the reindeer buck are made into "finnesko," the most useful form of winter boots, by treatment for twenty-four hours in a strong decoction of birch or similar bark. The skin of the hind legs is used for the soles and sides, and that of the fore legs for the

upper leather, the hair being left outside. Those boots are worn with the fur outside, and may be filled inside with a sedge or "sennegroes." They are very suitable both for ski and Canadian snow-shoes.

The northern races of Europe and Asia have domesticated the reindeer. The standard of wealth of the Lapp is according to the number of reindeer he possesses. It is his all in all. The reindeer transports his household and himself from one place to another; it supplies him with milk and meat; it clothes his family and himself. Its bones form needles, and its sinews threads. Its bones also make spoons and other useful articles of equipment. All and every part of a reindeer—living or dead—is indispensable to him. For food the reindeer is never at a loss, even fending for itself when winter snow covers the ground. With its hoof the reindeer scrapes away the snow and discovers underneath the reindeer moss—a lichen which forms a favourite food.

It is pitiable to see this graceful and useful animal ruthlessly slaughtered, as it has been in Spitsbergen during recent years, and it is discreditable to relate that a person of exalted position has been one of those who have set so deplorable an example. Norwegian hunters are also greatly to blame—not even hesitating to use strychnine and other poisons, and thus

decimating not only reindeer but also bears, foxes, birds, and other animals, and transforming fertile Spitsbergen into a barren cemetery.

It is impossible to describe the Arctic mammals species by species, and it is indeed difficult to know where to draw the line. The elk or moose (*Alces machlis*) ranges north of the Arctic circle, and has to withstand Arctic conditions of weather, but it is a forest animal, and along with a host of other mammals may be regarded as subarctic rather than Arctic. The Arctic hare (*Lepus timidus*), on the other hand, is a mammal that penetrates the northernmost of Arctic lands, being widespread over the Canadian Arctic Archipelago up to 83° N. latitude. It is very widely distributed over northern Europe and Asia, extending from Ireland to Japan. It is common in Scotland, where it is known as the blue or mountain hare.

Wolves (*Canis lupus*) are common all over the Canadian Arctic Archipelago and Greenland, as well as foxes, of which there are many varieties. The silver or black fox (*Canis vulpes*) is said to be a variety of the ordinary British fox, and is almost the most valuable of all foxes. It is entirely black except the tip of the tail, which is usually white. The silvery lustre is due to grey rings which usually mark the black hairs on the head, the hinder half of the back, and the thighs.

The blue fox (*Canis lagopus*) is next in value. Its coat remains blue all the winter, the hair lengthening considerably. The Arctic fox, which may be a variety of the blue fox, has a short greyish brown and white coat in summer, and a long white coat in winter. I believe these two forms seldom, if ever, interbreed. These foxes are exceedingly numerous in all parts of the Arctic Regions, and frequent especially the many great bird rookeries that occur in Arctic lands. They are among the most characteristic animals of the Arctic. They used to be in great numbers in Prince Charles Foreland, where the Scottish Expedition carried out survey work during three summer seasons, but the advent of the Norwegian hunter with his traps and his devilish poison has almost exterminated them. In 1906 and 1907 hundreds of these animals were seen, but in 1909 they were practically non-existent, none having been seen by any of the *Conqueror's* party, and only one having been heard barking although almost every part of the island was traversed by the explorers. This beautiful animal is extraordinarily bold, though it can scarcely be said to be tame. The Scottish explorers in 1906 and 1907 had these animals coming to within a few feet of them, eating the fat out of the frying-pan of the canteen, stealing the sugar, bacon and other food-stuffs, feeding even out

of the hands of the explorers, and sleeping within a few yards of the tent, preferably on the tops of the covered caches of provisions. On one occasion when standing cooking by the canteen I had emptied a tin of condensed milk and had dropped it on the ground, when a fox came between my legs from behind and made off with the tin which was lying between the canteen and myself. Yet for all their boldness and audacity, it was impossible to catch them, for while giving them bacon or something else out of your hand, and watching an opportunity to pounce upon them and secure them, the fox too had its pair of wonderful eyes fixed upon yours and was ready at the slightest sign of any hostile move on your part. When I have been chaining, I have known them lick the fat off the steel measuring-tape, and bite off the straps of my sextant-case lying on the ground a few yards from me.

In August they lie in wait in shallow holes in the ground, watching the young looms (guillemots) coming down from the cliffs accompanied by the old birds. Should the young bird fall short of the sea, the fox immediately seizes it, provided the chick has escaped the fate of being swallowed whole by a glaucous gull. On one occasion I was watching, under cover of a large rock, two or three foxes lying thus in wait. Presently a young loom accompanied by its mother came flying down

from the rocky cliffs above, and fell short of the sea. The devoted mother landed near by to urge its young on to the sea and safety, but the nearest fox, swift as lightning, in bee-line, head down, eyes absolutely fixed on the old bird, made a rush on its desired prey. Both fox and loom were out of range of my gun, but, instinctively wishing to succour the weaker one, I ran towards the spot where I thought they would meet and at long range fired just too late, the fox dropping to my shot in the very act of plunging its teeth in the loom's neck. The swiftness of the whole act was the remarkable feature of this striking scene.

Speaking of lemmings (*Myodes torquatus*) in Grinnell Land, Admiral Markham says, "These little mouselike creatures are the smallest yet the most numerous and common of all quadrupeds in the Arctic Regions. They are extremely pugnacious and fearless, and often attract attention, when they would otherwise be unobserved, by their shrill cries of rage at an approaching step. They hibernate in burrows under the snow, and live during the summer on the scant vegetation of these regions." With epicurean satisfaction the explorer further narrates, "When roasted and served up on toast, like sparrows, they were found to be excellent eating, although provokingly small." They have been met

with on the sea ice three miles from the nearest land. There appear to be no lemmings in Spitsbergen or Franz Josef Land, but otherwise they occur in all Arctic lands, and spread themselves far south in Europe, Asia, and America. Brehm has graphically described the countless swarms of lemmings that sweep the tundra, leaving a track of desolation in their rear.

Such is the mammalian life of Arctic lands; think of the contrast in Antarctica, where, in an area of five and a half million square miles, or a continent the size of Europe and Australia combined, there is not a single mammal! Nor, as far as we know, did mammals ever exist in that mighty continent at any time!

Just as Australia was cut off from northern lands before the advent of the carnivores or any of the higher mammals, so there seems good evidence that the great continent of Antarctica, which appears to have been connected at one time with Australia, New Zealand, South Africa, and South America, was isolated before the advent of mammals in the Trias, in which system the first relics of mammalian life appear. The land connections of Antarctica with adjacent continents have been dated even as late as Eocene times. "The exact date at which the Antarctic continent had its great extension northward can perhaps hardly be definitely

decided upon at present. Hutton argues for the Jurassic period as the period of greater extension; but since he wrote much further evidence has arisen, and it seems probable that the date should be placed later—perhaps in Eocene times. Ortmann, discussing the matter from a somewhat different aspect, considers that it probably occurred in the Cretaceous and Eocene periods" (Dr. C. Chilton, in *Subantarctic Islands of New Zealand*. vol. ii, p. 807: Philosophical Institute of Canterbury, 1909). But even if Antarctica was united at later times to Australia or to the southern extremities of South America and South Africa at the time the western and more ancient part of Australia possessed "the ancestral forms of its strange marsupial fauna, both of which it had probably received at some earlier epoch by a temporary union with the Asiatic continent over what is now the Java Sea" (*Island Life*, by Alfred Russel Wallace, p. 497), we could only conceive of marsupial forms occurring on the continent of Antarctica. It is quite clear from the fossils brought home by Dr. Donald of the Scottish Expedition of 1892–93, by the more recent able researches of Dr. Otto Nordenskjold and his companions during the Swedish Antarctic Expedition of 1901–4 in the same region, as well as by the researches of Dr. Pirie of the *Scotia*, the naturalists of the

Discovery and of Sir Ernest Shackleton's recent expedition, that at one time, certainly in Jurassic times, there must have been a temperate if not a subtropical climate over Antarctica. Therefore, if there happened to be land connection with Antarctica at even as late a date as I have, for the sake of argument, supposed—and there is so far no evidence that there was—it would have been possible, under those conditions of climate, for marsupials to exist. But with the changed conditions of climate it does not seem likely that they or their descendants could possibly survive. It is therefore not surprising that there should be no mammals in Antarctic lands, though they are abundant in the Arctic, where there are even now plentiful connections with lands largely occupied by mammals of almost every description.

But if the Antarctic lands are desolate of mammals it is not so with the Antarctic seas. As in Arctic seas, whales and seals abound in enormous numbers, except where they have been annihilated by man. Of the whales very little is known. Ross described a whale "greatly resembling, but said to be distinct from, the Greenland whale." But so far no such whale has been seen by other explorers or whalers within the limit of the pack ice, although we know of at least two other right whales in subantarctic waters. Finners

(*Balænoptera*), humpbacks (*Megaptera*), and thrashers (*Orca*) have, however, been recorded, and on the edge of the ice, blackfish (*Globiocephalus*). These great whales very often occur in immense schools in Antarctic seas. The Scottish Expedition of 1892–93 passed through thousands of finner whales. On December 16, 1892, many came quite close to the ship, and, as far as the eye could reach in all directions, one could see their curved backs, and see and hear their resounding blasts. During recent years these whales have been greatly hunted by Argentine, Chilian, Norwegian and British Whaling Companies, in the same manner as similar whales have been hunted in northern European and Spitsbergen waters. Whaling stations have been set up by these companies on the South Shetlands (Deception Island), South Georgia, and more recently at the Falkland Islands, and the results of these fishings have been a very handsome dividend to the shareholders. The southern right whale (*Balæna australis*) is also caught by these whalers. It is reported, however, although this industry has been established only for five or six years, that the numbers of the whales have already markedly diminished. But these whales penetrate well into the pack, where the small iron steamers dare not follow, so there is yet a chance that they will not be altogether exterminated. The

purely commercial aspect of these whaling expeditions has, so far, made it impossible to make any detailed scientific cetacean investigation. A most profitable scientific investigation would be a cetacean expedition, which devoted its whole time with two or three ships to the study of these Antarctic whales, and, indeed, to the study of whales all the world over. It is not possible for an Antarctic exploring ship, with so many other duties to perform, to carry out this very important work.

In Arctic seas the most notable whale is the Greenland or Bowhead whale (*Balæna mysticetus*) which has been captured in enormous numbers in the past. In the seventeenth century there was a Dutch settlement called Smeerenburg, in the north-west of Spitsbergen, where the oil was boiled down and the whalebone collected. As many as 2,000 people lived and worked there during the summer months, women as well as men, as any one visiting Spitsbergen at the present day can determine by reading both men's and women's names on the old Dutch wooden crosses, that have stood there in some cases for three hundred years, and many of which are still in a good state of preservation. Coffin after coffin is seen projecting half above the ground; human skulls and bones lie in and around them.

Other species are similar to those of the Antarctic seas, but not nearly so numerous, and besides these there are two worthy of special mention, namely, the White whale (*Delphinapterus leucas*) and the Narwhal (*Monodon monoceros*). The white whale is found skirting the shores of almost every Arctic land, and is very easily distinguished by its cream-coloured skin; so regular are its movements along a coast that skilful hunters seldom fail to secure the greater part of a school of them by knowing that they will travel along a certain coast by a certain route. They are driven ashore by means of boats and nets. They yield a considerable amount of oil, and their skins are manufactured into "porpoise" boot-laces. The narwhal is nearly allied to the white whale, but is easily distinguished by the male's single long spiral ivory tusk, often 7 or 8 feet long, which has earned for it the name of "unicorn," or "uni," by whalers. It is hunted by whalers for the value of the ivory of the tusk and for its oil; the tusk is usually developed on the left side, but occasionally two are developed. It has a circumpolar range. (For a fuller account of Arctic whales and seals than is possible here, see papers by Dr. R. Brown on "Seals of Greenland and Spitsbergen Seas" (*Proceedings Zoological Society, London*, 1868, pp. 405–438), and on "Cetacea of Davis Straits

and Baffin Bay" (*P.Z.S.*, 1868, pp. 533–556). Both papers, in revised form, in *Arctic Manual and Instructions*, 1875).

Four species of seals are known to inhabit Antarctic seas. The first concrete accounts of these animals were brought back by Weddell, D'Urville, Wilkes, and Ross. But it was not until after the departure of the Scottish Expedition in 1892 that much was known about them. The best known and most widely distributed is the Weddell seal (*Leptonychotes weddelli*) which is found on, or near, all Antarctic shores. The least known is the Ross seal (*Ommatophoca rossi*); this is the rarest true seal in the world. Very few of these have ever been seen, and not many occur in collections. The other two species are the Crab-eating or White Antarctic seal (*Lobodon carcinophaga*) and the Sea-leopard seal (*Stenorhyncus leptonyx*). The latter is a very remarkable seal, noted for its litheness and swiftness. It chases, catches, and feeds on penguins in the sea. Mr. Wilton, of the *Scotia*, records that "a sea-leopard was observed to catch a black-throated penguin by the leg and haul him down in the water."

Another true seal occasionally penetrates the pack, but is really an inhabitant of sub-antarctic lands and seas: this is the Great Sea-elephant seal (*Macrorhinus leoninus*), the

male of which measures about twenty feet in length.

The Southern Fur seal (*Otaria australis*) is also an animal that is confined to subantarctic and south temperate seas. It does not enter the pack. Much could be said about this interesting animal, concerning the enormous numbers, the animal's habits and home, and how stupid seal-hunters destroyed a valuable industry for half a century by massacring millions of these fur seals, not hesitating to kill mothers suckling their young, which perished in hundreds of thousands (*Pinnipeds*, J. A. Allen, Washington, 1880, p. 230).

Arctic seals, like Arctic birds, are more numerous in species, but probably not in numbers of individuals. Bloody slaughter is recorded in the north as in the south, especially in the case of the Walrus (*Trichechus rosmarus*), which has been absolutely exterminated in some parts of the Arctic, where formerly it used to occur in great herds (*Seasons with the Sea Horses*, Lamont, 1861).

Much has been written recently regarding the great fur-seal fisheries of Alaska and the Behring Straits, and Labrador, but those Fur seals (*Otaria ursina*), like their cousins in the south, are subarctic rather than Arctic; they keep outside the polar pack. The real Arctic seals are, with the exception of the walrus, like the Antarctic seals, all "true or earless

seals," that is, Phocidæ. There are several species, notably the Greenland seal (*Phoca grœnlandica*), the Bearded seal or square flipper (*P. barbata*), the Ringed seal (*P. hispida*), the Floe-rat (*P. fœtida*), the Hooded or bladder-nosed seal (*Cystophora cristata*). Of these probably the Greenland seal is the commonest. These animals assemble in immense herds, especially on the ice in Newfoundland seas. "In Greenland the annual catch was estimated at 33,000, while that in Newfoundland used to exceed 500,000, and in Jan Mayen seas the total number killed each year was fully 30,000." Fortunately the killing of these seals, like that of the fur seals, is now regulated by law, and although they may sometimes be over-killed, yet there is not altogether reckless slaughter. The bearded seal is the largest of Arctic seals, and although it is not so large as some Antarctic species, yet it may attain a length of about ten feet. Like other mammals in Spitsbergen, all these seals have been largely killed out in that archipelago.

The birds of the Polar Regions are a characteristic feature, and again there is the striking fact that, although Arctic lands teem with many species of birds, there are, with the exception of the migratory Chionis, no Antarctic land birds. This is probably due in part to the geological reasons that explain the absence of mammals, in part to

the obvious difficulty of fragile land birds getting to Antarctic lands across the wide expanse of the stormy Great Southern Ocean, and also in part to the fact that, if they did arrive there, they would find hardly any suitable nesting-place, and would be without their necessary food supply on account of the scarcity of plant life, especially the practical absence of flowering plants and flower-visiting insects. Scoresby, in the neighbourhood of Scoresby Sound at Cape Swainson in 71° N. on the east coast of Greenland, says, "Numbers of winged insects, however, were met with, particularly on the hills among the stones. These consisted of several species of butterflies, with bees and mosquitoes! Near the beach were several plants in flower, with a few that were further advanced and in a state of fructification." What a paradise for Arctic land birds, and what a contrast to the barren rocks of Antarctica, almost completely obliterated with ice and snow! How could there be land birds in Antarctica?

Arctic land birds are full of interest, but it is impossible to enter into any detail concerning them here. The reader should look into the works of Seebohm, Feilden, Harvie-Brown and Pearson, as well as the delightful pictures of tundra life that Brehm gives. (For the natural history of Arctic birds reference should be made to the following:—*From North Pole to*

Equator, A. E. Brehm; *Beyond Petsora Eastward*, Henry J. Pearson, with appendices by Colonel H. W. Feilden, C.B.; *The Birds of Siberia*, Henry Seebohm; *Travels of a Naturalist in Northern Europe*, J. A. Harvie-Brown.) The most typical of all Arctic birds is the Snow Bunting (*Plectrophenax nivalis*), which is in immense numbers, and which finds a home and nesting-place in every Arctic land, no matter how bleak. The snow bunting arrives in Franz Josef Land about the middle of April, and has been recorded to remain plentifully until October 14th, and stragglers not leaving until October 30th, three days after the disappearance of the sun in that latitude, viz. 80° N. The nests, which are made of dried grass and feathers, are built among stones, under shelter of over-lying rocks, in rock crevices, and under peaty banks. There are usually five to seven eggs. The young birds have been recorded as early as July 10th in Franz Josef Land. The Purple Sandpiper (*Tringa striata*) is the next most plentiful Arctic land bird. It is usually the first bird that meets the Arctic explorer on landing. The first sandpiper of the season recorded in Franz Josef Land was seen on May 29th. Late in June eggs were found, and on July 4th the first young sandpipers were captured. The nest is built in a hollow among Arctic willow, lichen, and the like, and is very difficult to see, either when the

eggs are bare or when the bird is sitting upon them, because of the remarkable resemblance of the bird, eggs, and nest to its surroundings. One may almost tread on the bird before it will rise, and even then the nest is difficult to find. A known nest at a definite number of feet in a certain direction from a prominent mark is very difficult to see. Of course, this may also be said of many other birds and eggs, but it is perhaps as pronounced in the case of the purple sandpiper as any other bird. There are many other birds that could be noticed—the Knot (*Tringa canuta*), whose eggs have only recently been found; the Sanderling (*Calidris arenaria*); the Grey Phalerope (*Phalaropus fulicarius*); the Dunlin (*Tringa alpina*); the Little Stint (*Tringa minuta*), which Pearson found breeding in such numbers in Novaya Zemlya; the Lapland Bunting (*Calcarius lapponicus*), Redpoles (*Linota*) and many others of the smaller birds too many to enumerate. Then there is the Ptarmigan (*Lagopus rupestris* and *L. hemileucurus*), and the Willow Grouse (*Lagopus albus*), which vary their plumage with the season, so that they are at all times very much in accord with their surroundings, whether the snow is white or dirty yellow, or whether they are sitting among lichen-covered stones. These birds form most excellent food, the ptarmigan being common to almost all Arctic lands, even

beyond the 83rd parallel of north latitude. Birds of prey, notably the Snowy Owl (*Nyctea scandiaca*) and the Greenland Falcon (*Falco candicans*) are also characteristic birds in many Arctic lands.

But when we come to consider sea birds, then the Antarctic Regions are as rich as the Arctic Regions, if not in species, certainly in numbers. The two most characteristic orders of birds are penguins and petrels. Besides these there is a shag, one gull, two skuas, and two terns. The penguins literally swarm in millions, and occupy every available space of bare ground near the sea that is not ice-covered. These crowded areas recall the remarkable bird cliffs and isolated bird islands of the Arctic Regions. So numerous are penguins even in subantarctic islands that sealers have resorted to the barbarous method of boiling these birds down indiscriminately for the sake of the valuable oil that they contain. This custom has been rightly put a stop to in some British possessions. The most remarkable penguin that exists in the Antarctic Regions is the Emperor penguin (*Aptenodytes forsteri*), which, though not so numerous as other species, is found in very great numbers in certain places, as, for instance, Victoria Land, Coats Land, and other lands that are situated well within the ice limit. It is the handsomest and largest of

all penguins, an adult, when in good condition, weighing about eighty pounds.

D'Urville was the first to discover and bring back to Paris the egg of the Emperor Penguin, but nothing was known about the breeding habits of this remarkable bird until Dr. Wilson and the naturalists of the *Discovery* brought back the first description. The bird builds no nest, but sits on the ice and lays a single egg, which it places on the top of its feet and covers by a flap of skin and feathers. The egg being laid before the winter is over and hatched before the advent of spring, there is heavy mortality among the chicks. The chick is nestled on the feet of the parent bird, and kept warm like the egg by the flap of skin and feathers, which surrounds it almost like a marsupial pouch. In spite of the care thus taken of the chicks, many die from exposure, and each bird if it has not a chick of its own is anxious to secure one from its neighbour. The early breeding of the Emperor Penguin has possibly arisen from the necessity of giving sufficient time by the end of the summer for the young bird to develop to such a stage of maturity that it can by that time fend for itself.

Other penguins are all very much smaller than the Emperor, weighing about 8 to 14 lbs.; the most plentiful and characteristic species is the Black-throated penguin

(*Pygoscelis adeliæ*). This species is common to every Antarctic seaboard that explorers have yet visited. The *Scotia* naturalists estimated that, on Ferrier Peninsula alone, which was for two or three miles simply alive with these birds, there were not less than two millions. Altogether, in Laurie Island, South Orkneys and its off-lying islets, no less than fourteen rookeries were known, besides the Ferrier Peninsula rookery. The favourite sites for these communities were on rocky places near the sea, where small stones abounded, and these were sometimes occupied up to 500 ft. above sea-level. As the season advanced these rookeries became indescribably dirty, being masses of mud, with pools of filth, and the birds themselves became correspondingly defiled.

At the rookeries in Scotia Bay the first signs of nest-building were noted (1903) on October 10th. By the 20th nearly all were paired, and the appearance of an unpaired bird gave rise to a fearful commotion, every bird trying to get a billful of feathers from the unhappy one, while all the penguins in the vicinity raised their voices and screeched their loudest. The appearance of such wanderers, too, generally resulted in a free fight among those around.

The nests are built of stones, which the penguins gather often from a long distance,

and they may be lined with a few stray quills and a bone or two. Every bird is an accomplished thief, and whenever possible steals stones from its neighbour's nest. There are usually two eggs. The first egg found by the *Scotia* naturalists was taken on October 29th; on October 31st no less than 739 eggs were gathered from the same rookery, and between November 2nd and 10th no less than 2,075 eggs were taken for domestic use. The period of incubation is about thirty-two days. Both the flesh and the eggs of this penguin form very nutritious and palatable food. Besides the black-throated penguin, it was estimated that there were at least 100,000 Gentoo penguins (*Pygoscelis papua*) in the Scotia Bay rookeries. The naturalists of the *Scotia* were fortunate in falling in with a great number of the Ringed penguin (*Pygoscelis antarctica*) at the South Orkneys at several rookeries, notably at Ellium Isle and Saddle Island. At a rookery on Mackenzie Peninsula there were about a quarter of a million of ringed penguins, and the rookery at Saddle Island was tenanted by about 50,000 birds. They were entirely absent during the winter, not reaching the South Orkneys till November 2nd. Over 1,000 eggs were taken by Dr. Pirie on December 12th, at the Mackenzie Peninsula rookery. There is one very remarkable discovery the *Scotia* naturalists made with regard to the young

of this bird, and that is, that the chick has two stages of down. This is a most interesting discovery, for no other bird is known to have more than one down stage. These are the four species of penguins characteristic of the Antarctic Regions, though the golden crested or Marconi penguin (*Catarrhactes chrysolophus*) is also recorded from the South Orkneys as a straggler, and breeds at the South Shetlands. Thus it is seen that there are several million penguins of at least three species on South Orkneys alone! Imagine the legions that swarm on every possible Antarctic coast!

Among the important ornithological results of the Scottish National Expedition, not the least striking were the investigations made by the *Scotia* naturalists on petrels. Wilson petrels (*Oceanites oceanicus*) were found breeding in considerable numbers, and several eggs were obtained. They had only previously been found breeding on Kerguelen. The occurrence of the Black-bellied stormy petrel (*Fregetta melanogaster*), says Mr. Eagle Clarke, "was one of the most interesting ornithological discoveries made by the expedition. It implies a remarkable extension in its known range, and removes the doubt which has hitherto overshadowed the record of its having bred at South Georgia, as mentioned by Pagenstecher, in the southern summer of 1882–83."

Other interesting discoveries made by the

Scotia naturalists were the finding the eggs of the Cape pigeon (*Daption capensis*) and the young of the Snowy petrel (*Pagodroma nivea*). From their observations, too, it may almost certainly be forecasted that the Antarctic fulmar (*Thalassœca antarctica*) and the Silver petrel (*Priocella glacialoides*) will be found to breed in the South Orkneys. Such a series of records made in one order of birds in one locality by the efforts of Mr. Wilton, Dr. Pirie and Dr. Rudmose Brown, apart from many other valuable records, may safely be said to be without parallel in the history of Polar exploration.

Petrels, next to penguins, are scattered most widely all over the Antarctic Regions, and are in most cases common, not only in that region, but also in the Great Southern Ocean, where many other species which do not penetrate into the ice zone occur. One of the most striking of these is Wilson's petrel, which can be followed from British waters to the farthest southern limit of Antarctic seas, and which is found breeding, as I have indicated, in the South Orkneys, Kerguelen, and probably other Antarctic islands. In all probability the birds in British waters breed in Antarctic islands! This fact is hardly conceivable when we consider the proportions of the bird, which are much the same as those of a swallow, but the same remark-

able fact appears to hold good for the Arctic tern, which breeds in the Arctic Regions, and which was discovered by the *Scotia* naturalists to be spending its days, during the northern winter, in the seas off Coats Land!

Ross regarded the presence of the Snowy petrel as a sign of proximity of the Antarctic pack, and this observation appears to be perfectly correct, for there are few days, whilst navigating in the pack, that one does not meet this graceful bird. It is circumpolar in distribution, and breeds in most inaccessible cliffs on nearly all Antarctic coasts. For three hundred years the Cape pigeon has been known to every South Sea sailor, but the eggs were first taken by Dr. Pirie on the cliffs of Mount Ramsay, on the west side of Jessie Bay, South Orkneys, in 1903. This species which we are inclined to regard as the most plentiful bird in the world, will probably be found to breed on most Antarctic and subantarctic islands, and on many parts of the coast-line of Antarctica, and is found scattered over the whole of the vast Southern Ocean from 35° S. to the edge of the Antarctic continent. Fully 50,000 of these birds breed in the South Orkneys. Their nests, composed of small angular fragments of rock and some earth, are placed on the ledges of precipitous cliffs. The Cape pigeon, like other petrels, has the habit of

ejecting from its tubular nostrils a red, oily, foul-smelling fluid, composed of the half-digested remains of crustaceans (*Euphausia*). The naturalists visiting the nests had to risk having this fluid squirted over their face and clothes. The birds can squirt this fluid to a distance of six or eight feet. The Cape pigeon often allowed itself to be captured on its nest. The eggs, which are pure white, are laid singly, and are very large for the size of the bird.

Besides these there are many other petrels recorded in Antarctic seas, and perhaps the best known of these is the Giant petrel (*Ossifraga gigantea*) called also the Nellie and the Stinker. Why sailors should have called this bird a "Nellie" I do not know, but the name "Stinker" is quite appropriate, on account of the curious, unpleasant, and persistent odour it possesses. Not only does the bird have this odour externally, but even its flesh and eggs have the same smell. The *Scotia* dogs readily ate penguins and other birds, but would not eat the flesh of the giant petrel. The weight of this bird varies from 7¼ to 10 lbs., and it looks nearly the size of a swan. The plumage varies from white, through grey, to almost black. These varieties appear to interbreed. The nest is a large pile of subangular stones, in the form of a truncated cone; and usually only one large white egg

is laid. The nellie's gluttonous habits are well known to South Sea sailors; feeding ravenously on the remains of slaughtered seals or refuse, and filling itself to repletion till it is almost comatose, it is unable to rise from the ground till it disgorges the contents of its stomach. I have seen these filthy birds, feeding on the carcase of a seal, move off a few steps and disgorge what they had devoured and then begin to eat again.

Although a shag had previously been noted in the Antarctic Regions, the specific identity of these Antarctic shags remained somewhat uncertain until the Scottish Expedition finally settled the matter at the South Orkneys, in 1903, by finding it was the Blue-eyed shag (*Phalacrocorax atriceps*).

The Dominican gull (*Larus dominicanus*) is not very plentiful and does not appear to cross the circle. The Antarctic skua (*Megalestris antarctica*) and MacCormack's skua (*M. maccormicki*) are typical Antarctic birds: the former is very plentiful in the South Orkneys and other less southern Antarctic islands. The latter is more associated with higher southern latitudes. Antarctic skuas are very ferocious birds, and they will fight with each other to the death.

The two terns are the White-rumped tern (*Sterna hirundinacea*), which breeds plentifully on Antarctic islands, and the Arctic tern

(*S. macrura*). Mr. Eagle Clarke is of opinion that the Arctic tern does not breed in the Antarctic Regions, but that it is a summer visitor during the Arctic winter. Mr. Clarke says, "The finding of this tern in the seas off the South Polar continent must be regarded as one of the most important ornithological discoveries made by the Expedition (*Scotia*), for, as has already been stated, no terns appear to have been previously captured within seas girdled by the Antarctic Circle."

But besides whales, seals, and birds, Polar seas teem with lowlier forms of animal life from fishes down to simple unicellular animals, and it is all this vast host of fishes and invertebrates that accounts for the large number of mammals and birds in Polar Regions—north and south. These lowlier and mostly smaller forms of animal life depend, as already indicated, upon the meadows and pastures of the oceans which are made up of immense quantities of unicellular algæ. Fishes and invertebrates occur everywhere in Polar seas, from the surface down to depths of about 2,000 fathoms in the Arctic Regions, and to depths exceeding 3,000 fathoms in the Antarctic Regions.

It would be entering into too large and intricate a subject, and too technical a one, to attempt to discuss Polar invertebrate life in

the present volume. It is also dangerous at the present time to formulate general statements regarding the distribution and general laws which regulate this host of living beings, as Polar exploration is as yet in its infancy, as far as serious research in this subject is concerned. Still there are one or two points that may already be gleaned from the oceanographical research of several of the recent expeditions to the Arctic and Antarctic—notably those of Leigh Smith, Payer, Nordenskjold, the Prince of Monaco, Duke of Orleans, Nathorst and others in the north, and those of the *Challenger*, *Valdivia*, *Belgica*, *Scotia*, *Discovery*, *Gauss*, *Français*, *Antarctic* and *Pourquoi-pas?* in the south.

One forecast of importance that may be made is regarding the theory of "Bipolarity," in which it is suggested that species of animals in Arctic seas find, as it were, their reflected images represented by species in Antarctic seas.

A few years ago the case was doubtful. But modern Polar exploration, especially in Antarctic seas, with the tendency to explore more thoroughly definite areas, by vessels carrying on board a much larger number and more highly trained staffs of naturalists, to whom better opportunities are being given to carry out their special work, has rather revealed the fact that such similarities which

could support the theory of bipolarity do not occur. Nay, even this interesting fact seems to be brought out—that, to a large extent, the invertebrate fauna that inhabits one area of Antarctic seas is not the same as that which inhabits another. The invertebrate animals taken by the Belgians and the French to the west of Graham Land are markedly different in many respects from those taken by the Scots and the Swedes to the east of Graham Land. The English also obtained in the Ross Sea different species from those obtained by the Scots and Swedes, Belgians and French, or Germans.

Examination of the results of the deep-sea trawling shows that, although in shallow water quite a number of new species were obtained, forming but a small proportion of the whole number of animals collected, the list of deep-sea species shows that almost every animal obtained in deep waters and in high southern latitudes is new to science. These facts should give an indica-cation of the scientific value from a zoological point of view of deep-sea exploration in the Antarctic Regions. Take any group whatever and it will be found that the greater portion of animals obtained in deep Antarctic waters are new to science.

With the exception of that great Scottish navigator and explorer Sir James Clark Ross,

who led the way to deep-sea exploration with efforts which Sir Joseph Hooker has described as almost incredible, and who was the first and only one for many a year to bring back examples of deep-sea animals from the Antarctic Regions, Polar explorers until quite recent years have not considered it an important part of their programme to investigate the physics and biology of Antarctic seas.

The *Challenger*, which was not an ice-protected ship, and which did not include Antarctic exploration as part of its programme, did, nevertheless, in 1874, cross the Antarctic Circle, and made one trawling in 1,675 fathoms only slightly north of the Circle, and made other deep-sea investigations in relatively high latitudes. The *Valdivia* also carried out valuable oceanographical researches in similar latitudes a little further west than the *Challenger*. But of recent Antarctic expeditions the *Belgica, Scotia, Gauss, Français*, and *Pourquoi-pas?* are the only ones that have made oceanographical research a special aim. The *Scotia*, besides being strongly fortified to battle with ice, was better equipped as an oceanographical ship than any Antarctic ship has ever been, and was thus able to carry out most important investigations in very deep water in high latitudes.

In the scientific work carried out on board

the *Erebus*, Hooker especially supported Ross, and Sir John Richardson in his report on "The Zoology of the Voyage of H.M.S. *Erebus* and *Terror*," says the warmest thanks of zoologists "are due to Dr. Joseph Dalton Hooker for his able co-operation with his commanding officer, and for the excellent sketches and notes which he has contributed." Hooker was the sole worker of the townet, bringing the captures daily to Ross and helping him with the preservation of marine animals, as well as with drawing a great number of these animals for him. The zoological collections of that expedition were most important and furnished the first evidence that a rich fauna existed in Antarctic seas at all depths from the surface to the bottom. The deep-sea exploration of the *Challenger* in relatively high southern latitudes furnished further concrete evidence that there existed in Antarctic seas a very rich fauna of fishes and invertebrates, and also indicated to us that great results might be obtained by an exploring ship equipped for deep-sea work that was also fitted out for doing that work well within the Antarctic ice-pack. The *Valdivia* in 1898 explored as far south as 64° 14′ S. off Enderby Land, and made extensive biological collections especially in plankton.

But it was the *Belgica* in 1897–99 that first successfully carried out marine biological

investigation well within the Antarctic Circle. During a cruise and remarkable drift south of 70° S. latitude between 80° and 102° W. longitude, as well as during her more easterly cruise along the west coast of Graham Land, frequent dredgings were made which resulted in a very remarkable collection of deep-sea marine animals being secured. Most of this collection was made in water of about 200 or 250 fathoms; but north of 70° S. a few dredgings were made in depths of more than 1,400 fathoms. The reports on this rich collection of Antarctic marine animals are now nearly completed in a large series of valuable volumes giving an account of the scientific results of the voyage. Never before had such a large collection of marine animals been made in the Antarctic Regions. Fishes, echinoderms, crustaceans, polychæts, gorgonids, bryozoa, and, in fact, representatives of almost every order of invertebrates, were obtained. The *Gauss*, *Discovery*, and *Antarctic* (1901–4) were a series of expeditions which continued the exploration of the sea in relation to marine animals, but their work was not nearly so comprehensive in this direction as that of the *Belgica*. The *Gauss* trawled in greater depths, but not nearly in such high southern latitudes. The work of all these expeditions has, however, added considerably to our knowledge of Antarctic invertebrate

zoology, and not least of all the fine work done by Mr. T. V. Hodgson, who made the greatest possible use of every opportunity that was given to him. To Hodgson is entirely due the fine invertebrate records the *Discovery* brought home.

But it was left to the *Scotia* to carry on more extensively than any other Antarctic expedition has ever done marine biological research, and also to carry on that research in very deep water well south of the Antarctic Circle. Altogether the *Scotia* dredged 150 times in water varying between 4 and 161 fathoms, and had traps down on 250 days, hauling them up and rebaiting them 200 times. But besides this, the *Scotia* trawled 18 times in water exceeding 1,000 fathoms, 15 times in water exceeding 1,500 fathoms, 11 times in water exceeding 2,000 fathoms, and 4 times in water exceeding 2,500 fathoms. Most of these trawlings were taken south of 60° S., whilst navigating well within the Polar pack and among bergs. On account of the constant presence of ice the greatest possible vigilance and care was required in handling the trawling gear. Sometimes the trawling cable would catch on a floe, which would add several tons pressure to what the cable had already to bear. On such occasions the great mass of ice might be carried down below the surface to quite a considerable distance, until some-

thing destroyed the equal balance that held it, when it would rapidly rise to the surface and shoot out endwise far above the water. When this happened the ship had to be handled in such a way as to avoid if possible the severe shock it would sustain from the blow of such a huge piece of ice, weighing many tons and as hard as rock. But even when it was impossible for the ship to escape the blow, it was of vital importance to handle her in such a way that the rudder and propeller were not damaged or carried away by the impact of the ice. This was the first time that deep-sea trawling had been attempted in the ice-pack, and if under ordinary circumstances in the open sea great care, accuracy, and considerable practice are required to carry out the operation successfully, much more so was that the case on the present occasion. The *Scotia* trawling cable was capable of withstanding a strain of more than nine tons, and on more than one occasion the dynamometer showed a strain of more than six tons. Every thousand fathoms of the trawling cable weighed a ton, and on several occasions the *Scotia* had as much as 4,000 fathoms, *i. e.* 4½ miles, of cable paid out. It can be understood, therefore, that the operation was no child's play, and that the 40-horse-power winch, the derrick, the blocks and every portion of the working

gear had to be in as perfect condition as possible to avoid any accident. Yet, in spite of every precaution in the course of this arduous work, more than once the lives of men were endangered. I have undertaken arduous sledging and other land work within the Arctic and Antarctic Regions, but I know of no work that is more difficult or more dangerous than trawling in the greatest depths of the ocean in a sea closely packed with ice. The great increase of strain on the cable when it is caught by the ice, which is unavoidable, and the sudden release of strain, it may be to the extent of even 3 or 4 tons, tells to the utmost on all the gear, and it is not unlikely that something may give way with disastrous results. Such accidents are most likely to happen in the early part of a voyage, before everybody is thoroughly familiar with the operation. On one occasion the trawling-cable drum on the *Scotia*, containing 6,000 fathoms of cable weighing over six tons, "took charge," and the bo'sun had a miraculous escape, and on other occasions other members of the expedition had their lives and limbs endangered. These incidents are only mentioned here to let the reader understand that Polar explorers carrying on their researches at sea encounter perils at least as great as those making long journeys on the land.

During the winter alone in the South Orkneys, in Scotia Bay and Jessie Bay, the Scottish naturalists caught upwards of 2,000 fish, which served not only for zoological requirements, but also as an excellent supply of fresh food. Besides fishes, examples of almost every class of invertebrate animals were secured. So large are the collections of the Scottish Expedition alone, that it is difficult to do more than refer the reader to the official reports. But it will give a good idea of what the result of the deep-sea trawling operations were, if some quotations are given from these volumes. Here is one from the author's own log, which gives some idea of a day's work at trawling, as well as of a zoological catch, in the far south, and in tolerably deep water. "March 18th, 71° 22′ S., 16° 34′ W. Barometer falling slightly, 29·206 to 28·84 inches, temperature steady, 28° to 29° F. Wind, gentle, with westerly breezes till 8 a.m., N.E. to N. afterwards. Fine clear though overcast weather, with occasional light showers of snow. We sounded from 6.45 a.m. to 8.15 a.m., in 1,410 fathoms, and took five serial temperatures from surface to the bottom. The trawl with 2,400 fathoms (= 2¾ miles) of cable out, which registered a strain of 2½ tons, brought up one of the two richest hauls we have had, that of the Burdwood Bank possibly equalling, but scarcely surpassing it—and this

one, on account of the greater depth and high southern latitude in which it was taken, is certainly by far the most important we have had. Two very large-stalked sponges, both new species (*Caulophacus scotiæ* and *Malacosaccus coatsi*), besides two others, three or four very large purple holothurians, a quantity of brilliant red crustacea, probably *Crangon*, two species of isopods, five or six chætopods, three or four gasteropods, two masked with anemones,—a large number of very hard and large sea-anemones of a pale-greyish and lavender colour, about three species of brittle stars, five species of fish including one of a beautiful blue and delicate grey-lavender colour, and one of which we only secured the head, which was remarkable for its crocodilian appearance, with its long and toothed jaw,—some ctenophores, and jelly-fish, not in good condition,—bryozoa and probably sertularians and alcyonarians,— altogether fully sixty species; specimens which, for their striking variety of colour and form as well as from their large number, could not fail to strike the most casual and least interested individual. Yet ignorant people tell you there is no life in the Antarctic!"

As an example of disappointment it may be mentioned that on the following day, in a depth of 1,221 fathoms, the trawl was lowered, putting out 2,000 fathoms (= 2¼ miles)

of cable, but it did not touch the bottom, and this occurred more than once in this locality. The only way that this could be accounted for was that there were strong under-currents sweeping the trawl off the ground; for during the previous year, in about 2,500 fathoms, bottom was reached with 3,100 fathoms of cable, or only 600 fathoms extra beyond the depth, instead of 800 as on this occasion.

On the 21st of March, however, in lat. 69° 33′ S., 15° 19′ W., the *Scotia* secured a good haul in 2,620[1] fathoms (= 3 miles) on a bottom of blue mud. In order to make sure of the trawl reaching the bottom, we fixed four furnace bars, each weighing 22 lbs., and two olive-shaped weights on the cable, each of 20 lbs. An extra 1,000 fathoms of cable were let out, that is to say, 3,620 fathoms (4⅛ miles) in all. The trawl began going out at 10.15 a.m., and was on board again at 6.33 p.m.; this time there had been about 500 fathoms of cable on the bottom, showing that we could have done on this occasion with our usual allowance of 500 or 600 extra fathoms. The dynamometer registered up to 5 tons. The trawl came up with a great deal of mud and many big stones, and the following animals :—one fish, a siphonophore

[1] At 2,620 fathoms there is a pressure on any object of about 2½ tons per square inch, reckoning 1 ton per 1,000 fathoms.

tentacle about 600 fathoms from the end of the cable, arenaceous worm tubes, two species of asteroids, one species of ophiuroid, four species of holothurians, broken bits of echinoids, a medusoid, probably from the surface, two species of fixed stalked colonial cœlenterates, two species of sponges, and some species of foraminifers (*Zoological Log of the "Scotia,"* Edinburgh, 1908).

Besides trawling on the bottom, the Scottish Expedition used other means of catching animals living in Antarctic seas. They followed the excellent practice of the Prince of Monaco by using large baited traps, resembling in principle the common lobster pot or creel, extensively employed by fishermen of Scotland and other countries. These traps consist of a light framework of wood covered with herring-net, with two funnel-shaped entrances placed in suitable positions through which fishes and other creatures swim or crawl into the trap, and being unable to find their way out again are captured. This valuable form of apparatus was first used in the Polar Regions by the author in 1896, in Franz Josef Land, and since that time has been used by many Polar expeditions with success—notably by the Prince of Monaco himself in Spitsbergen Seas; and in the Ross Sea by Hodgson, following the advice of Armitage and Kœttlitz, both of whom had seen it used with

such success in Franz Josef Land. During the wintering of the *Scotia,* these traps were used extensively, several of them being put out in different depths and at varying distances from the ship. The *Scotia* also used these traps in a depth of 161 fathoms off Coats Land.

Mention has already been made of the use of fine silk tow-nets, which were used to get samples of diatoms and other algæ drifting about on the surface of the water. These nets, while doing their botanical scouting, also gather small marine invertebrates drifting or swimming freely on or near the surface of the sea. This "plankton" investigation forms one of the most interesting forms of Polar exploration, and the *Belgica,* the *Gauss,* and the *Scotia* all carried out extensive investigations in this direction in Antarctic seas with very important and interesting results. But besides using such nets on the surface, the Polar explorer uses them, like other explorers of the sea in other parts of the world, for ascertaining what creatures are drifting or swimming in intermediate depths between the surface and the bottom.

The nets used for this purpose are of various sizes and shapes, the smallest may be two inches in diameter, the largest many feet: the Prince of Monaco uses a vertical plankton net 15 or 16 feet in diameter; the largest

net the *Scotia* used was eight feet in diameter. The most generally useful size and that most frequently employed was, however, one of four inches diameter, and three feet in length, made of the finest Miller's silk, which catches almost all the minutest forms except possibly cocospheres and rhabdospheres. (The finest Miller's silk, known as No. 20, has 5,926 meshes to a square centimetre: each side of the mesh is 0·05 mm. long.) The larger nets are made of coarse muslin. Among the various designs of these plankton nets some are devised to open and close at definite depths, so that a definite stratum of the sea may be explored to see what animals live there; others are so constructed as to enable an approximate estimate to be made of the number, as well as of the species, of animals that live in a certain volume of water. All these different kinds of nets were extensively used on board the *Belgica*, *Gauss*, *Scotia*, *Français*, and *Pourquoi-pas?* and less extensively on other recent Antarctic exploring ships. The *Discovery* and *Nimrod* did not use these nets or other marine biological apparatus so extensively, because their explorations were more specially on the land rather than the sea. The *Scotia* used an 8-foot vertical net as far south as 71° 50′ S., 23° 10′ E., lowering it there to 1,000 fathoms below the surface. The handling of these

delicate nets within the pack is by no means easy, and cannot very often be carried out. Through a hole in a continuous field of ice, such a net can be lowered with relative safety, but in the drifting pack it may be very difficult and often quite impossible. The successful accomplishment of this delicate operation by the *Scotia* demonstrates to what a state of proficiency the officers, staff, and crew had attained in the handling of this and other deep-sea gear, and it is a matter of deep regret that such a ship, on which so much thought, ingenuity, and money had been expended, had to be sold for "an old song," and such a set of men, who had come to know how to carry on not only such important deep-sea exploration, but to pursue it in high latitudes within the pack ice, had to part once more, to scatter all over the face of the globe, never again to meet together to carry on such important work for the advancement of science, which is always for the good of mankind.

The handling of a trawl among the pack is difficult, even dangerous, on account of the heaviness of the gear and the great and often sudden strains that occur. With the large fine tow-nets there is no danger, but the apparatus—winch, wire, and net itself—are all of such a light description that, if the wire or net gets entangled on pieces of

pack ice, they are apt to get damaged or carried away. Consequently the greatest vigilance has to be used: long poles have to be in readiness to push the heavier pieces of ice away from the place where the net is expected to come to the surface by the people on the ship and on the ice itself. The winch-man has constantly to be on the alert to "heave gently!" "stop!" "heave gently!" or what always produces such a cheery effect, "heave away!" Nothing is more exciting, nothing more intensely interesting than to hear the merry winch under perfect control heaving in the vertical net, or the trawl culminating in the final act of "taking it aboard." Reaching the South Pole isn't in it! At the beginning of such a voyage of exploration there are apt to be smiles at the eager zoologist emerging pale from his laboratory, but after the first time the trawl comes on board with its wonderful burden of living things of every colour and shape, each more quaint or beautiful than its neighbour, everybody on board becomes almost as enthusiastic as the zoologist who, now that he has got his sea-legs, feels himself more on an equal footing with his breezy seaman companions.

Off Coats Land, the highest southern latitude in which a vertical net has been successfully used, it is recorded by Wilton in

the *Zoological Log of the "Scotia,"* that the haul was a rich one, containing five species of fishes, and at least fifteen species of other animals, including "several examples of Salpa, four species of crustaceans, many specimens of *Sagitta*, several ctenophores, four species of medusoids, and some broken pieces of a jelly-fish." The examination of these specimens found in the vertical net on this occasion is a very useful indication to the reader of what "drifting life," or plankton, is in Antarctic seas, and one wonders at the delicate nature of most of the forms captured in these waters, which are at or about the freezing-point of fresh water, and often considerably below, especially when one knows that a considerable number of these forms must have been taken near the surface, where the ice-pack grinds and crushes in all its fury during violent storms.

So much for the zoology of Antarctic seas. One thing is perfectly clear, and that is that there is an immense field for most interesting exploration of the most useful kind open to those who wish to explore in the South Polar Regions. There is no form of exploration more fascinating and more important than oceanography—physical and biological—in any part of the world, and in no region is it more interesting and important to carry on these investigations than in the seas round

about the South Pole. Interesting as is the exploration of Antarctic lands, the exploration of Antarctic seas is not less so.

Neither is the exploration of these seas accompanied by fewer privations, difficulties, and dangers. In recent years no one has had a more exciting or adventuresome experience than Captain Adrien de Gerlache, during that remarkable drift in the South Polar pack for nearly a whole year, when human beings for the first time spent a winter in the Antarctic Regions. The adventures of the relief party of the Swedish Expedition are unsurpassed in the history of Polar exploration. Caught in the pack, their ship, the *Antarctic*, was crushed like a match-box, and left them stranded on the pack many miles from land. With almost superhuman effort they reached the land, but cut off from two men they had landed at another place with a tent and a few days' provisions, and without having been in sight of the main encampment that they were to relieve. It was about twelve months before these three parties were to meet together, and, wonderful to relate, they and the Argentine relief ship *Uruguay* all met within a few hours of each other. Lastly, the world has learnt of the difficulties and dangers that the gallant French explorers had under the able leadership of Dr. Jean Charcot,

who hammered out the Western record to 124° W. along the 70th degree of south latitude, knowing that the ship's keel and planking had been ripped off on the rocks of the west coast of Graham Land (*Le Pourquoi-pas? dans l'antarctique*, by Dr. Jean Charcot: Paris, 1910).

The biology of Antarctic seas is perhaps more interesting and important than that of Arctic seas for reasons which will be afterwards considered. Although a great deal of zoological research has been carried out in the Arctic seas from time to time, that research had been much less systematic than in the Antarctic Regions, because in the Arctic Regions it began before zoology was organised as it is now. At a period when practically no research was being carried out in Antarctic seas, many of the earliest writers have given descriptions of northern invertebrates. Martens, for instance, gave excellent descriptions of the animals he saw in Spitsbergen, both on the land and in the sea, during his voyage in 1671. Not only his text, but his excellent drawings show what an accurate and close observer he was: he has fair pictures of seals and walruses, remarkably good drawings of the Greenland whale, and a number of interesting ones of invertebrates such as *Gorgonocephalus*, two other ophiuroids, a *Caprella*, two medusoids, also the well-

known pteropod (*Clio borealis*), all of which can easily be identified. After Martens, there are no very accurate descriptions of Arctic marine invertebrates until the beginning of the nineteenth century. At this time Scoresby was one of the best observers. The first man to give us a concrete idea of animals that lived in the deep Arctic waters was Sir John Ross, who initiated his nephew, James Clark Ross, in that work which, as already mentioned, he afterwards carried out successfully in Antarctic seas. Baron Nordenskjold did really good systematic marine zoological work; and after him Payer and Weyprecht, during the German Expedition of 1870 to East Greenland and the Austrian Expedition of 1874 to Franz Josef Land. In 1897 the author brought home large zoological collections from Franz Josef Land. Major Andrew Coats' expedition to the Barents Sea and the Prince of Monaco in Spitsbergen seas in 1898 also carried out important marine biological research. During that year and in 1899, 1906, and 1907 the Prince of Monaco and Dr. Jules Richard trawled, trapped, and tow-netted several times in high latitudes and deep water in the Greenland Sea. Since 1898 many others, including the Duke of Orleans, Nathorst, and Amundsen have done similar work, so that altogether we have a very considerable knowledge of the fishes and inverte-

brates of the Greenland, Spitsbergen, and Barents Seas, as well as those of Davis Strait and some of its sounds.

One of the characteristics of the Arctic, like the Antarctic, marine fauna is the enormous number of individuals of certain species, specially some of the amphipods, copepods, and echinoderms. Two species of amphipods (*Anonyx nugax* and *Onissimus edwardsii*) swarm in such quantities in Arctic seas that the carcase of a large bird will be entirely cleared of soft parts by them, and a well-cleaned skeleton is left in twenty-four hours. Such a tough morsel as a bear's skull, if lowered into water of 10 or 20 fathoms, will be beautifully cleaned in the matter of a few days. Naturalists have often resorted to this method to help them in their work.

In a depth of 197 fathoms at the entrance of Ice Fiord, Spitsbergen, the Prince of Monaco obtained in a trap no less than forty pounds of large, red prawns (*Pandalus borealis*), altogether 1,775 specimens; not only were these prawns interesting zoologically, but they were found to be an excellently delicate food, and were used on board for that purpose. A sea-urchin (*Strongylocentrotus droëbachiensis*) is enormously plentiful, and so are some species of brittle-stars. The water teems with pteropods, especially *Clio borealis*, the food of the Greenland whale, and arrow-worms

(*Sagitta*), with their transparent houses. In the Barents Sea I have gathered a pound or more of small copepods (*Calanus finmarhicus*) in my tow-net in the space of a few minutes. These enormous swarms of animal life form the basal food supply of the myriads of birds, and herds of seals and walrus, and the numerous whales. And it should always be remembered that man himself, when the worst comes to the worst, can find abundant food in the small crustaceans of the sea, if he has any means of catching them.

Though collecting animals and plants that live in Polar seas, and enumerating species is of great interest, much more than that is required of the modern biologist. He must try to find out what is the reason of there being certain species in Polar seas, of their being such enormous numbers of certain species, and the relationship which this marine life has to marine life in other seas. It is of immense interest when we discover facts regarding life in Polar seas that have a distinct bearing on human economy. A beginning of such discoveries has already been made, although we still see "as through a glass darkly."

CHAPTER VII

PHYSICS OF THE POLAR SEAS

THE first step in marine biological investigations, whether in the Polar sea or elsewhere, is the study of the physical conditions under which the marine forms of animals and plants live, and correlation of these observations in various seas. Hence the study of the physics of the oceans as a whole is most important, and it becomes the duty of a Polar explorer to carry on that research in the Polar seas. The first essential in any form of oceanic research, after knowing one's position on the earth's surface, is to know the depth, and if this has not already been determined one must take a "sounding." To be able to sound accurately in all depths is the first accomplishment of the practical oceanographer. In the Arctic Regions bathymetrical survey has been of the most irregular and piecemeal character, although on the whole we have now a fairly complete knowledge of the conformation of the floor of the North Polar Basin and the seas adjacent. Most of these soundings have been secured in the

course of ordinary navigation, but Sir John Ross and his nephew took a number of soundings in a thoroughly systematic way. During recent years we have a good line of soundings across the Polar Basin taken by Nansen and Sverdrup during the drift of the *Fram.* The author took a large number of soundings during 1896, 1897 and 1898, on board the *Windward* and on board Major Andrew Coats' yacht *Blencathra* in the Barents Sea, from the shores of Europe to Novaya Zemlya and Franz Josef Land, and between Hope Island and Spitsbergen almost up to Wiche Islands. The Prince of Monaco and the Duke of Orleans have made series of interesting and important soundings between Spitsbergen and Greenland as far as 81° N., while Baron Nordenskjold, Leigh Smith and Makarof have sounded to the north of Spitsbergen. Amundsen, Sverdrup and others have taken soundings in the straits and sounds of the islands of the Canadian Arctic Archipelago. The most important work done by Peary during his last expedition was a series of soundings along his route to the North Pole which indicated more or less the conformation of the Polar Basin according to ideas established largely by Nansen's soundings. But it is most unfortunate that in the most important of these soundings Peary did not actually touch bottom. It

would have been of more interest than any other observation that this Polar enthusiast could have taken at the North Pole, had his lead touched bottom, and had he brought back a sample of the deposit at the bottom of the sea at the Pole itself.

In the Antarctic Regions there has been a much more systematic bathymetrical survey, because, with the exception of Ross, practically no soundings were taken until the *Challenger* sounded in the vicinity of the Antarctic Circle off Termination Land. Before Ross, the early South Sea voyagers had no conception of deep-sea soundings. Weddell sounded in 71° 25′ S. "The water again being discoloured," says Weddell (*A Voyage towards the South Pole*, 1827), "we sounded with 240 fathoms of line, but got no bottom, though I am of opinion it would have been obtained at a greater length of line; but as we had no more, nor a lead sufficiently heavy, we could not be so experimental as I wished." According to the *Scotia* soundings there was a depth here of about 2,000 fathoms, and no doubt Weddell little guessed how much "greater length of line" he would have required to touch bottom. All the recent Antarctic expeditions have taken soundings in Antarctic and subantarctic seas, but by far the most important series taken are those of the

Scotia. Altogether the *Scotia* took seventy-five deep soundings in the South Atlantic Ocean, and Weddell and Biscoe Seas, besides nearly five hundred soundings in the neighbourhood of the South Orkneys in water of less than 100 fathoms. Twenty-six of the seventy-five deep-sea soundings were taken south of the Antarctic Circle, and fifty were taken whilst navigating actually in the pack ice; forty-three were taken in water exceeding 2,000 fathoms, twenty-three in water exceeding 2,500—ten of the last being south of the Antarctic Circle. The deepest sounding was 2,900 fathoms, or a depth of three miles and a quarter, in 39° 27′ S., 5° 17′ E., between Gough Island and Cape Town.

The *Valdivia* carried out an important bathymetrical survey to the south-east of South Africa and the *Challenger* and the *Gauss* farther to the eastward. The *Belgica* and *Pourquoi-pas?* took a number of soundings from Graham Land to 124° W. between 69° and 71° S., which are of great importance, most of them being between 200 and 300 fathoms and indicative of the presence of continental land not very far to the south in these longitudes. The great interest of the *Scotia* soundings, along with the discovery of Coats Land, was to give an entirely new idea of the southward extension of the Weddell Sea, and to alter previous ideas

of the depths of that sea which were all based on a very deep sounding taken by Ross in 68° 32′ S., 12° 49′ W., which was believed by him to be "4,000 fathoms no bottom," but which was proved by the *Scotia* to be 2,660 fathoms, the Buchanan sounder bringing up "blue mud." Ross's error was due to the very primitive gear he had on board for so great a depth. Instead of working with a compact machine from the ship itself, and having the valuable assistance of steam, and instead of working with apparatus that has taken sixty years to bring to its present state of perfection, this old veteran and pioneer of deep-sea exploration did wonderful work with very rude apparatus and gave us much information about ocean depths in many parts of the world. Ross did all his sounding from boats lowered for the purpose, and his hemp line was laboriously hauled in by hand on large cumbersome drums by his crew. This example of patience and endurance deserves all praise, and it would be well if it were followed in these days. Ross's line evidently sagged, after the weights had touched the bottom—if they touched at all—the line being carried away by the strong currents that exist in that region, currents which prevented the *Scotia* trawl from reaching bottom on three occasions in spite of extra weights being attached and a large amount of extra cable being paid out.

A theory has been advanced by Dr. H. O. Forbes (*Supplementary Papers, Royal Geographical Society*, 1893) that there existed at one time a land connection between New Zealand and Eastern Australia by way of the Chatham Islands and Antarctica, and also that there had been a connection between Madagascar and South America and Antarctica. The soundings of the *Scotia* substantially support the latter part of Forbes' theory by showing the existence of a long ridge or "Rise" (a "rise" is a ridge rising up from the bottom of the ocean to within 2,000 fathoms of the surface), about 300 miles in breadth, extending in a curve from Madagascar to Bouvet Island, and from Bouvet Island to the Sandwich Group, where there is a forked connection through the South Orkneys to Graham Land, and through South Georgia to the Falkland Islands and the South American continent. Thus Antarctica, South America and Madagascar, and probably South Africa, become connected with one another in a most direct manner by this "rise." As Dr. Pirie has pointed out, the existence of sedimentary rocks in the South Orkneys, as well as in South Georgia, points to a much greater extension of land to the south-east of South America in former times. The Scottish Expedition made another great discovery, namely, that the "Mid-Atlantic Rise"

extended 1,000 miles farther south than was previously supposed, and that in all probability it connected at its southern extremity with the rise between Bouvet Island and the South Orkneys and South Georgia. This extension of the Mid-Atlantic Rise is now known as the "Scotia Rise."

These investigations tend to show a separation between the "deeps" ("deeps" are those parts of the oceans which are deeper than 3,000 fathoms) discovered by the *Valdivia* lying to the south-east of Bouvet Island, which may be suitably known as the "Ross Deep," and the deep lying to the south-west of South Africa, as well as that deep lying to the north of South Georgia and to the east of Argentina; all these "deeps" are separated from one another by "rises" of less than 2,000 fathoms.

The work of the *Challenger*, *Valdivia*, *Gauss* and *Scotia* in the South Atlantic and South Indian Oceans has given us a clue to the possible connections between Africa, South America and Antarctica, and now it is of great interest and importance to get more soundings to the south of Australia and New Zealand, to show more exactly what the conformation of the floor of the ocean is in those longitudes. That is one of the most important investigations for future Antarctic exploring ships to carry out.

The bathymetry of the Arctic Ocean is simple compared with that of the Antarctic Ocean, and consists of a basin almost completely surrounded by land, which does not appear to be anywhere much deeper than 2,000 fathoms, the three deepest soundings taken by Nansen and Sverdrup being 2,195 fathoms, 2,102 fathoms, and 2,020 fathoms. Unfortunately, in the three soundings these explorers took between 15° E. and 70° E., including the farthest north one, they did not succeed in reaching the bottom, these three soundings being "1,638 fathoms no bottom." Within five geographical miles of the Pole Admiral Peary obtained a sounding of "1,500 fathoms no bottom." Where the North Polar Basin is not bounded by land, as at the Behring Straits and between Spitsbergen and Greenland, it is bounded by ridges of considerably less than 2,000 fathoms in depth. The researches of the Duke of Orleans and the Mylius Erichsen Danish Expedition tend to show that a ridge covered by quite a small depth of water exists between Spitsbergen and Greenland.

A proper conception of the bathymetry of Polar seas is necessary for an adequate discussion of physical problems connected with the temperature, salinity, specific gravity and circulation, and the effect of wind, air-temperature and other phenomena that

affect these seas. The physical problems of ice-covered seas are much more complicated than in seas where there is no ice, because, as we have seen previously, when the surface of the sea is being frozen over, the salt in that part of the water which is changed into ice is thrown out and must therefore make the neighbouring water more saline; on the other hand, when that ice melts during the following summer it adds a considerable amount of fresh water to the sea in its neighbourhood.

The salter water would naturally have a higher specific gravity than the fresher water, but it is not unlikely that the fresher water produced from melting ice may, by virtue of its being colder than the neighbouring more saline water, actually have a higher specific gravity. The presence of icebergs, which in the south are of enormous size and very numerous, and which even in the north are very numerous in certain districts, must produce an enormous amount of fresh water during the summer and quite sufficient to affect the salinity of the sea where they occur. One of the most interesting features of Arctic waters, especially between Greenland and Spitsbergen and to the north of Spitsbergen well into the Polar Basin, is the existence of an intermediate layer of comparatively warm water in the Arctic Ocean between the surface

colder water and the colder water beneath. This was observed as far back as the beginning of the nineteenth century by Scoresby and subsequently by many other observers, among whom are Admiral Markham, Maury and Leigh Smith, and in more recent years by Nansen, the Prince of Monaco, the Duke of Orleans, the author, and many others. A century ago Scoresby said, "On my first trial, made in the summer of 1810, in latitude 76° 16′ N., longitude 9° E., the temperature at the depth of 1,380 feet (230 fathoms), was found to be 33·3° (by the water brought up), whilst at the surface it was 28·8°. In nearly twenty subsequent experiments, an increase of temperature was in like manner discovered on bringing water from below, or on sending down a register thermometer to a considerable depth. In one instance (the latitude being 79° N. and longitude 5° 40′ E.) there was an increase of 7° of temperature on descending 600 feet; and in another series of experiments, near the same place, an increase of 8° was found at the depth of 4,380 feet (730 fathoms)." Recent Scandinavian observers tend to claim this as a special discovery of their own, and have omitted any reference to the work of former explorers, and in the case of one man, Benjamin Leigh Smith, this is especially ungracious.

Leigh Smith was one of the first to carry

out investigations on this intermediate warm layer in a systematic manner during his cruise in Spitsbergen seas in his 80-ton schooner *Sampson* in 1871. Leigh Smith's observations were some of the earliest, and were most important; but, owing to his modesty, they have not been taken sufficient notice of either in Britain or abroad; Scandinavian oceanographical investigators have been especially remiss in this direction. "Honour where honour is due!" so we wish here to honour this gallant Arctic explorer —the hero of five Arctic voyages, the discoverer and cartographer of the western half of Franz Josef Land, the most remarkable leader of a band of men, whose ship was crushed in the ice off Franz Josef Land and went down in a quarter of an hour. Leigh Smith, most ably supported by Dr. W. H. Neale, afterwards wintered with his twenty-five men in an improvised hut with practically no food but bear and walrus, and during the following summer effected his own relief by conducting those twenty-five men—loyal because of their trust in him and love for him—in open boats among the Polar pack to Novaya Zemlya over a distance of 500 miles during six weeks. And, let all Scandinavian ocean physicists especially remember, that Leigh Smith was the saviour of Baron Nordenskjold's expedition

of 1872–73 from starvation and death in the north of Spitsbergen, and by his good mapping the able guide of Nansen and Johansen in the last lap of their remarkable journey across the Polar Basin. Let these Scandinavians remember what Nordenskjold, the greatest of Scandinavian explorers, afterwards wrote, when the Swedish expedition had separated from Leigh Smith, namely, that "it was he who was to render it (the Swedish expedition) so great a service, and bind its members to him for ever in the bond of gratitude and attachment"; and again, when Nordenskjold says, "May we be permitted publicly to express the deep gratitude of all of us to Mr. Leigh Smith for the costly and welcome gift, and to assure him that it will be long before the members of the Swedish Polar Expedition of 1872–73 forget the *Diana's* visit to Mussel Bay."

It is not creditable to Britain that this most worthy and modest Englishman has never received acknowledgment of his distinguished services in Polar exploration by the Government of his own country.

This intermediate warm layer of water, at least in the region of the Greenland Sea and to the north and east of it, appears to be due to the warm water of the Gulf Stream, which, having greater density due to its salinity, dips underneath the upper colder layer, form-

ing a distinct intermediate stratum. With all due respect to certain scientific people who deny that the Gulf Stream reaches the shores of Britain and Spitsbergen, I consider it quibbling to deny its existence and call this well-known phenomenon by some other name. Surely the finding by Torell in Spitsbergen in 1861 of the West Indian Bean *Entada gigalobinum* is sufficient evidence alone—call it drift, current, stream, or what you will. To the Gulf Stream is largely due the open conditions of the seas on the west of Spitsbergen, and, under certain conditions, north-eastward even to the north of Novaya Zemlya and the shores of Franz Josef Land; it also influences to a considerable extent the climate of western Europe and Britain, keeping the Norwegian fiords free of ice throughout the winter.

Relative to investigations on the influence of the Gulf Stream on the Polar Basin, is work done in what one might call a subarctic region, namely in the Faeroe Channel, during the cruises of the *Lightning* and *Porcupine* in 1868 and 1869, where the flow of the Gulf Stream is north-eastward across the ridge, between the Faeroes and Iceland. In more recent years, the Scottish Fishery Board cruisers have made additional more detailed investigations as well as the Norwegian Fishery steamer *Michael Sars*. Many

of the most important and interesting problems regarding the physics of Arctic seas circle round the influence of the Gulf Stream.

The intermediate warm layer of water is not peculiar to the Arctic Regions. "The common feature of Antarctic water found by all expeditions," says Mr. J. Y. Buchanan, "is the thick warm layer lying between a cold layer at the surface and another cold layer at the bottom."

The intermediate warm layer in glacial seas was found by the *Challenger* in her Antarctic cruise. Although she was furnished only with the "Millar-Casella" thermometer, a protected maximum and minimum thermometer of the Six type, by the skilful handling of this instrument her staff was able to make a perfect thermometrical survey of the water from the surface to the depth where the maximum temperature of the first warm layer was found, which was at 200 fathoms, and to fix the superior and inferior limits to the temperature of all the water below (*Challenger Report-Narrative*, vol. i, Part I, p. 419).

Buchanan points out that, "One of the striking features of the ocean discovered by the *Challenger* expedition was the extensive area of very cold water which occupies the bottom of the sea from the east coast of South America to the ridge which runs north

and south in the meridian of the island of Ascension. Here the bottom temperature was found to be 32·5° F. The existence of this exceptionally cold bottom water was discovered on the outward voyage in soundings near the Brazilian coast, so that the expedition was prepared to take up the study of it on the way home. This was done very thoroughly on a line from the mouth of the River Plate along the parallel of 35° to the meridian of Ascension. The depth of water varied from 1,900 to 2,900 fathoms, and the distribution of temperature in the water was, roughly, a warm surface layer of perhaps 100 to 200 fathoms, then a thick layer of water of temperature about 36° F. down to 1,600 fathoms near the coast, and to 2,200 fathoms or thereabouts at sea. Here was a steep temperature gradient falling away rapidly from 35° to 33° F. and more slowly to 32·5° F. The occurrence of the steep gradient shows a renewal of the water and therefore a current. The observations of the *Valdivia* show a similar distribution in latitude 60° to 63° S., with this difference —that the surface layer is colder than the intermediate, being about 34° F. The bottom layer has as low a temperature as 31·5° F." Unfortunately at that time there were not enough determinations of temperature of the deeper layers to indicate the gradient

which separate the cold bottom water from the comparatively warm intermediate water, but now the additional observations taken on board the *Scotia*, *Gauss* and *Antarctic* should help to fill up the gap. The results of the extensive observations by these three expeditions will be an undoubted aid towards the solution of the meaning of this very cold water at the bottom of the ocean off the east coast of South America northward toward the equator. The lowest bottom temperatures obtained by the *Scotia* were 28·9° F. in 2,550 fathoms in 63° 51′ S., 41° 50′ W.; 30·95° F. in 2,547 fathoms in 64° 24′ S., 48° 18′ W.; 31·0° F. in 1,775 fathoms in 62° 10′ S., 41° 20′ W.

The bottom temperatures taken by the *Scotia* farther south are considerably higher, and in the vicinity of where Ross thought he had "4,000 fathoms no bottom," namely, in 68° 32′ S., 12° 49′ W., the *Scotia* obtained a bottom temperature in 2,485 fathoms of 31·5° F.

It is very tempting to suppose that, like the Gulf Stream in the north, there is a warm highly saline current pushing southward along the surface from the Atlantic, which dips under the colder but less saline water on the surface of the Antarctic seas, and that getting cooled, this water sinks whilst abutting against the Antarctic conti-

nent, and by the ever-flowing southward upper current is pushed northward underneath along the floor of the ocean, finding its way into the deeps to the east of South America. The *Scotia* salinity observations also seem to support this theory, especially the record in 159 fathoms two miles off Coats Land. But this hypothesis is here given with all caution, as the results of the observations of this and the other expeditions have not yet been fully investigated.

On board the *Challenger* Buchanan ascertained that this exceptionally cold bottom water near the coast of South America had a very high density, and this was confirmed by the observations of the *Gazelle.* "It is this density at constant temperature which decides whether a water can carry its surface temperature down to great depths, or whether it shall remain at the surface, and it is the annual range of temperature of such water which gives it its penetrating power" (*Proc. Royal Society,* 1875, vol. clvii).

I have specially referred to this cold water at the bottom of the deep waters of the Atlantic Ocean off the South American coast as an example of the intimate connection of Antarctic phenomena with those of other parts of the world, for here the interesting question arises, How far does this cold Antarctic water flowing northward at the

bottom of the Atlantic Ocean (if the conclusion is correct on the evidence we have at our disposal) not only affect the temperature, salinity and oxygenation of the waters of the Atlantic Ocean, but also, how far does it bring with it forms of Antarctic animal life, which help to populate the deep waters of the Atlantic Ocean in the vicinity of the equator? The question is an intricate one, and its solution will be largely helped by such work as the writer wishes to undertake in a second Scottish Antarctic Expedition, when an investigation of those seas which lie between the chief field of work of the *Scotia*, namely, the Weddell Sea, and that of the *Challenger* south of 40° S., is suggested as an important part of the programme.

This idea of the spread of animal life from the Poles to the equator is not new. Professor J. Arthur Thomson points out that "The generally accepted view is that the deep sea did not become a possible home of life until perhaps Cretaceous times, until the Poles cooled and the cold water rich in oxygen sank to the great depths. The affinity between abyssal animals and those found in shallower water in boreal seas has often been pointed out, and it is probable that the deep sea was largely peopled from the poles, or in any case from the shores" (*The International Geography*, 1907, p. 92).

That there is a strong underflowing current south of 70° S. in the vicinity of Coats Land is certain, for on three occasions the *Scotia's* trawl was prevented from reaching the bottom, evidently having been swept by such a current. It is not unlikely that it is the cooled intermediate layer that has sunk to the bottom which is being swept northwards towards the equator into the deep abysses of the Atlantic Ocean to the east of the South American coasts. There are many other fascinating problems of oceanic circulation that can only be solved by more extensive deep-sea research in the South Polar Regions.

There is little doubt, for instance, that there is a strong inflow of warm water between longitudes 170° E. and 180° E. where no ship has ever had any difficulty in reaching almost 78° S. Every ship that has ever tried has always been able to reach the foot of Mount Erebus and Mount Terror between these longitudes with comparative ease. Ross took the *Erebus* and *Terror*, and since then the *Antarctic*, the *Southern Cross*, the *Discovery*, the *Morning* (twice), the *Terra Nova* and the *Nimrod* have had the same experience, and now Captain Scott, doubtless with equal ease, if he sails between these longitudes, will take the *Terra Nova* again to McMurdo Strait without encountering any formidable pack-ice. Captain Armitage has told me that

on board the *Discovery* during her voyage southward along this route he had no ice navigation, except for a day or so in the vicinity of Cape Adare, and even that could have been avoided had he kept the vessel farther off the land. In spite of so many expeditions choosing this, the easiest route to the far south in Antarctic seas, we have not many serial sea temperature observations in these longitudes; consequently there is a fine field of work for future explorers, who are in command of well-equipped oceanographical ships, and whose programme, differing from the plans of previous expeditions to this region, is the exploration of the sea rather than the land, for this land has become specially well known owing to the splendid efforts of Scott and Shackleton.

Just as there are evidently inflows of warm water and outflows of colder water in Antarctic seas, so are there similar phenomena in Arctic seas. Reference has already been made to the Gulf Stream. One of the most marked of the cold currents is the East Greenland current, which has been known for a long time. Scoresby in 1823 pointed out that this main current along the eastern coast of Greenland "sets to the southwestward." He also pointed out a periodical offset and inset that occurred. Leigh Smith says, "Down the east coast of Greenland

there is an Arctic current about 200 miles broad, bearing on its surface a mighty floating glacier, which extends to Cape Farewell, a distance of 1,400 miles. The rate of this current is variously estimated from 5 to 15 miles a day." Captain David Gray in 1874, on board the *Eclipse*, records: "July 24th—Found by to-day's observations that we have driven forty-three miles S. by W. half W. true, in the past three days, and that in the face of fresh winds from S.W." The drift of the crew of the *Hansa*, 1869–70, also furnishes concrete proof of this current.

Thanks to this current flowing right across the North Polar Basin from east to west the *Fram* was able to drift across. It was owing to the same current that the relics of the *Jeannette*, wrecked to the north of the New Siberian Islands, were carried down the east coast of Greenland round Cape Farewell, and reached Julianshaab on the west coast of Greenland three years after the wreck of the *Jeannette*. The latest researches on this current were those made on board the Duke of Orleans's yacht, the *Belgica*. These observations add very materially to our exact knowledge of this interesting phenomenon.

A similar current runs south-eastward along the coast of Labrador and brings the Polar pack down to Newfoundland considerably south of the latitude of the south of Britain. This

is an excellent example of the economic importance of having an accurate understanding of the laws of oceanic circulation in the Arctic Regions and their relationship with neighbouring seas and coasts.

Antarctic deep-sea deposits (*Scotia* Deep-Sea Deposits, by Dr. J. H. H. Pirie, *Scot. Geog. Mag.*, Aug. 1905) furnish very strong evidence of the existence of a large continental land-mass around the South Pole. The chief research in this direction has been done by the *Challenger*, the *Valdivia*, the *Belgica*, the *Gauss*, the *Antarctic*, and the *Scotia*, and recently by the *Pourquoi-pas?*. From the results of these expeditions we find that between 40° S. and 55° S. there is a broad band of globigerina ooze, with patches here and there in deeper water, far from the land, of red clay. To the south of this band there is a band of diatom ooze to which reference is made in another place. This band forms a complete circle, generally speaking, between 55° S. and 60° S. We notice, however, that the band becomes very narrow in the Drake Strait, halfway between South America and Graham Land, where it stretches only between 58° and 60° S. On the other hand, it widens out very much to the south of South Africa, where the band stretches from about 44° S. to 60° S. To the east of this it appears to dip southward in the neigh-

bourhood of Enderby Land, but otherwise the distribution is much as has been already described. It would be of immense interest to dwell at length upon this remarkable deep-sea deposit, which is the most characteristic deposit of the Antarctic and subantarctic Regions, and which does not occur in other parts of the world except to a quite insignificant extent in certain places. To the south of this belt or band of diatom ooze we have a continuous ring south of 60° S., which is a deep-sea deposit of blue mud. In the Weddell and Biscoe Seas we have a small patch in the blue mud region which seems to be a sort of mixture of blue mud and red clay, and which is associated with the area of deep water mapped out by the *Valdivia* and the *Scotia*. A special point of interest in this blue mud deposit is found on examining maps of deposits in different parts of the world, when it is found that this deposit is always associated with continental lands. It occurs round the whole of the coasts of South and North America; round the coasts of Europe, Asia, and Africa. There is, in fact, no continental coast which is not bounded by blue mud. The natural inference, therefore, is that when we find blue mud surrounding an area of land about the South Pole that it is there in association with a great mass of continental land. It may here be men-

tioned that this blue mud has one character which is not common to other regions where that deposit occurs, for during the cruise of the *Scotia* there were taken up with the trawl many tons of subangular rocks, some of them weighing fully two to three cwts. The distribution, in the Weddell and Biscoe Seas of these great boulders, which show glacial erosion in having had their corners ground off, indicates that they have doubtless been carried out to the deep water of the Weddell Sea at the bottom of great icebergs that once formed part of, and have been calved from the great ice-sheet that probably flows northward from the South Pole over the Antarctic continent and finally break off at ice-faces bounding the Weddell and Biscoe Seas. Nothing would be more tempting than to discuss at greater length these deep-sea deposits, but that must be done at another time and in another place. Meantime the important feature to remember is the diatom ooze at the bottom of the Antarctic and subantarctic seas and the blue muds in the vicinity of all known Antarctic lands, indicating a greater extension of those lands and the existence of a great Antarctic Continent, further proof of which has already been given.

CHAPTER VIII

METEOROLOGY

NOT the least interesting study of the Polar Regions is from the meteorological aspect, and this seems to be especially so in the case of the Antarctic Regions. It seems extremely likely, if a set of permanent stations were established in the Antarctic Regions, with first-class equipment, thoroughly trained observers and not too few of them, that we might find the key for forecasting the weather not only of the southern hemisphere, but also, at least to some extent, that of the northern hemisphere also. One of the triumphs of the Scottish Expedition (1902–1904) was the meteorological work, and this was due to the fact that the *Scotia* had on board such an eminent practical meteorologist as Mr. Robert C. Mossman. Mr. Mossman conducted the chief meteorological station in Edinburgh; he had, besides, extensive practical experience of work on the summit of Ben Nevis, and at the head of Glen Nevis. The Glen Nevis station was especially for the study of the

Föhn winds. Before Mr. Mossman joined the *Scotia*, his field work and publications had placed him in the van of European meteorologists. Mr. Mossman was supported by two other trained meteorologists—the author, who had had experience for nearly two years at both high and low level Ben Nevis observatories, and who had been in charge of the summit observatory for more than a year, besides having had previous meteorological training and experience, and Mr. D. W. Wilton, who had also worked as an observer at both Ben Nevis stations, and who had been in charge of a smaller observatory half-way up the Ben for some months.

Thus, not only were there three thoroughly trained meteorologists on board the *Scotia*, a condition of efficiency not approached by any other Antarctic expedition, but each one of the three had experience of taking observations amid conditions of continual ice and snow. One had had experience of taking meteorological observations during long periods both in the Antarctic and Arctic Regions, and a second had had experience of taking meteorological observations for fifteen months in the Arctic Regions. Besides these three, Captain Robertson had taken meteorological observations in the Arctic and Antarctic Regions during many voyages. These facts are mentioned to emphasise the importance

of the *Scotia* meteorology, which has been enhanced by the fact that the results have been worked up by the man who conducted the work in the field, and who remained in the Antarctic Regions for another year, in the service of the Argentine Republic, after the *Scotia* had sailed for home.

Mr. Mossman has, since the completion of the Meteorological Reports of the *Scotia*, rejoined the Meteorological Service of the Argentine Republic, and a special part of his work there is in connection with the working up of the results of the Scotia Bay Station, which that energetic South American Republic has continued to support and direct during the past six years. The results of this work are already being felt. Before the *Scotia* had left the Antarctic Seas, Mr. Mossman was able to demonstrate meteorologically the existence of the land reported by Johnson and Morrell, extending northward to about latitude 65° S. in longitude 44° W., where both Ross and Crozier reported an "appearance of land," and where Nordenskjold's people on board the *Antarctic* also had possible "appearance of land." Nordenskjold dismisses the idea of land here because an iceberg was actually mistaken for an island at one time, and because of the depth obtained, viz. 2,031 fathoms. But Nordenskjold, according to his chart, was at least 40 miles farther off the point

where Ross and Crozier reported "appearance of land," "land blink," etc. (*Preliminary Chart, showing the Track of the "Antarctic" in Antarctica,* by Dr. N. Otto G. Nordenskjold and Dr. John Gunnar Andersson: London, 1905). The depth also is quite significant of land in these regions, for the *Scotia* obtained 1,746 fathoms fifteen miles off Coronation Island, and 2,370 fathoms only sixty miles off Coats Land. Mr. Mossman has pointed out that at Scotia Bay, South Orkneys, "the warmest winds are N.W. and N., and the coldest S. and S.E., there being a difference of 21·7° between the warmest and coldest directions. It is of interest to note the great difference between the temperature of west and south-west winds. On the mean of the seven months the south-west is 16·5° colder than the west, while in June the difference was as much as 22·2° F.

"From these observations it appears probable that there is a mass of land, the northern extremity of which is in lat. 65° S., long. 44° W., both Morrell and Ross having referred to an 'appearance of land' in this region. The circumstance that 'Föhn' winds blow from the west doubtless partly accounts for their relatively high temperature; but there are other reasons, notably the comparatively high barometric pressure experienced with south-west winds, which indicate a local

anticyclone in winter such as would form over a land surface."

Since that time, with the additional data furnished by the Scotia Bay Station during eight years, it has become more than ever certain that New South Greenland, as Johnson called it, really exists. The meteorological observations of the *Scotia* have also helped to prove that Coats Land is part of the Antarctic Continent.

If no other results of the *Scotia* meteorology than these two had been obtained, it would be acknowledged that those results were very valuable indeed. But Mossman has also found that there is a distinct relationship between the weather in Chile and the weather in the Weddell Sea. This is one of the most valuable economic results of the voyage of the *Scotia*. I will even venture to predict that the observations carried on at Scotia Bay, along with those in South America and South Africa, will be found most valuable in predicting the condition of the monsoons in India. Should this prove to be the case, it can then be said that the study of meteorology in the Antarctic Regions can be used for the alleviation of human suffering by enabling us to give sufficiently long warning to our fellow citizens of the Indian Empire to prepare for failure of crops, and ward off starvation and ruin.

The meteorological work of the *Scotia* has alone been mentioned, and that is because it is generally acknowledged that this work conducted by Mossman is the most important of all the meteorological work carried out by any of the Antarctic expeditions. But all the recent Antarctic expeditions have taken very careful series of observations, and these taken along with the *Scotia* observations form a most valuable addition, not only to our knowledge of Antarctic weather conditions, but to the meteorology of the world. Since the establishment of the Scotia Bay Observatories, the Argentine Republic have set up another station on South Georgia, and have considered setting up yet another on the west coast of Graham Land where De Gerlache and Charcot have done such very excellent meteorological work. Charcot's observations, having been synchronous with those at Scotia Bay and South Georgia, are very important. There is little doubt that more of these permanent stations in other parts of the Antarctic and subantarctic Regions working in conjunction with the two already mentioned and with the observatories not only in South America, but also in conjunction with those in South Africa, Australia, and New Zealand, would be a most valuable form of Antarctic exploration that would greatly increase our knowledge and benefit humanity.

It is not necessary to enlarge on the scientific value of such a network of meteorological stations in the southern hemisphere, where, on account of the huge expanse of ocean, atmospheric conditions are simplified and there are not so many of those disturbing conditions which upset the most careful calculations in the northern hemisphere, where the oceans are of less account, and only serve to separate from one another land masses of varying size and character. If all the surface of the globe were water or land of uniform altitude, meteorology would be simplicity itself, but as it is, it is one of the most complex sciences existing. It is, therefore, very essential to concentrate our energies on those parts of the terrestrial globe where conclusions are most likely to be arrived at concerning the general laws which govern the climate and weather of the world. In the far south the conditions are simpler than in any other part of the world, hence the importance of making a special study of meteorology round about the South Pole.

It is not so easy to place an economic, or even a scientific, value on the meteorological work that has been done in the North Polar Regions. It is very difficult to analyse properly Arctic observations, owing, as before stated, to the more complex distribution of land and water in that region.

But there is no doubt that one of the difficulties is the desultory fashion in which meteorological investigation has been carried out in the North Polar Regions, the international co-operation of 1881 and 1882 being the only instance where a systematic attempt was made to study the meteorology of the Arctic Regions as a whole, and even these stations were not in existence for a long enough period. Yet it was largely the study of these records that enabled Nansen to plan his expedition in the *Fram*, and to venture to boldly thrust his ship into the ice-pack, confident that the drift would carry it right across to the open water at the other side of the Pole. Peary, in his many sledging expeditions from the north coasts of Greenland and Grant Land towards the Pole, found the ice-floes always moving eastward, indicating a drift of the Arctic water in that direction. There is no doubt that a systematic study of the winds of the Arctic and subarctic Regions in relation to their cyclonic and anticyclonic systems is of the utmost importance, as upon these winds depend very largely the direction and flow of Arctic currents and Arctic ice-pack. Given prevailingly north-east winds over Franz Josef Land, even if they are very light, then the polar pack comes driving past that archipelago, not only the north but also the south of it by the straits between it and the

north of Novaya Zemlya. Jamming against the east coast of Wilczek Land, and against the north end of Novaya Zemlya, this southern pack sweeps westward across the northern portion of the Barents Sea, and, bringing up against the east coast of Spitsbergen, is forced past South Cape, and, during some summers like that of 1910, round South Cape, filling up Bell Sound and other western fiords in Spitsbergen with ice. On the other hand, if there is a prevalence of south-east winds in the Barents and Greenland seas, this pack is driven back, and the coasts of Spitsbergen, and even the southern shores of Franz Josef Land, are free of ice. This was the case in Franz Josef Land during the summer of 1897, and even during the previous midwinter, when there was open water to within a quarter of a mile of Cape Flora on the 24th of December, 1896. On the contrary, the wreck of Leigh Smith's yacht, the *Eira*, off Cape Flora in 1881, was due to a change of balance between the easterly and westerly system of winds, which caused the polar pack rapidly to close in upon the vessel, and crush it against the land floe. Leigh Smith had foreseen this, for he well knew how the movements of the pack depended on the wind, and, had his instructions been carried out, the *Eira* would not have been lost.

That part of the current which passes to the

north of Franz Josef Land from east to west, and which is largely dependent on the wind, was the current that carried the *Fram* across the Polar Basin from the New Siberian Islands to the north-west of Spitsbergen. Now these easterly and north-easterly winds that have been spoken of are the outflowing winds of the Eurasian anticyclone, as are the north-west winds blowing across the Himalayas and continuing as the north-east monsoons of India, and which prevail during January and February over India, that is, during the same time as the easterly and north-easterly breezes of the Arctic Regions. Now January and February is the period of the greatest intensity and extension of the great anticyclone, an intimate study of which from the North Pole to the tropic cannot fail to be of the greatest possible value for an accurate knowledge of that part of the terrestrial globe which contains about three-quarters of the inhabitants of the world. The ice movements which troubled Peary, and made his earlier attempts futile, and added difficulty and grave risk to his last successful journey to the North Pole, are also ultimately caused by the winds flowing from the great winter anticyclone of northern Asia.

This one example is a striking illustration of the value of Arctic exploration from a meteorological standpoint. During any

northern winter if this Eurasian anticyclone from some cause or other is not so intense or so extensive in area, it means that there is a breakdown of the north-east monsoons in India, and a breakdown of the north-easterly system in the Barents Sea. Hence, we have this further relationship, that if there is a breakdown of north-east monsoons in India, there is a minimum amount of pack ice in the Barents Sea and on the shores of Spitsbergen, which reminds one of Mossman's dictum, that the failure of the winter rains on the coast of Chile, south of lat. 33°, means that the Weddell Sea is comparatively clear of ice.

It must be emphasised that well-trained meteorologists are essential for conducting thoroughly satisfactory observations, for there are many errors that unguided amateurs are apt to commit, however conscientious they may be in the task set them.

The selection and setting up of instruments, either on board ship or ashore, is important. Before the departure of the *Scotia* I was aware that temperature observations on board ship were often vitiated by the warmth from the ship itself according to the relative direction of the wind. Yet, in spite of this well-known fact, I have not known any other ship but the *Scotia* fitted out with a double set of thermometers, one on the port side and the other to starboard. This was the arrangement

which Mossman, at my suggestion, adopted. Another important consideration in the placing of thermometers on board ship is to see that they are placed in a thoroughly exposed position in good louvred screens, which can get a free breeze across them: not up against a bulkhead or under a bridge or any other such place. On the *Scotia* they were fitted up against stanchions on each side of the quarter on the poop deck, about five feet above the level of the deck, and projecting as much as 18 inches clear of the ship's side, where they were in an absolutely open position.

When the temperature observations were being made the dry and wet bulbs on both sides of the ship were read, and the readings of those on the weather side were recorded as the correct ones. It is interesting to note that errors of several degrees were observed on the leeside thermometers on many occasions, especially when the *Scotia* was in high latitudes and low temperatures prevailed. Furnaces, galley and cabin stoves, and the general higher temperature of the ship itself all affected the readings. On rare occasions when the wind was absolutely ahead, and it was thought that both the port and starboard thermometers might be affected, Mossman used sling thermometers on the foc'sle head, but these, as a rule, did not vary a tenth of a degree Fahrenheit from the lowest read-

ing of the quarter thermometers. Furthermore, when the *Scotia* was wintering in Scotia Bay, and when there was a regular series of meteorological instruments set up in thorough observatory fashion ashore, it was found that the weather-side deck thermometers compared absolutely with those on shore.

"Except on rare occasions," says Mr. Mossman, "one side of the ship was definitely a weather and the other a lee side. It may be worthy of notice that there was usually a difference of one or two degrees between the weather and the lee side of the *Scotia*, the instrumental readings on the lee side being affected by heated currents from the cabins and engine-room,—hence the importance of having thermometer screens on both sides of the poop. On one occasion the lee side was as much as 5° warmer than the weather side, and on another occasion, during a calm, a difference of nearly 10° was noted."

A further check was afforded by the records of three Richard thermographs, which gave continuous records of temperature. Some little trouble was at first experienced by Mossman with the wet bulb thermometers, due to saline accretions on the muslin and bulb of the instrument, such as are formed on every exposed part of a vessel at sea. The result was that in the course of a week or so a coating of salt formed round the

bulb which could with difficulty be removed by scraping with a knife, or took some time to dissolve even when the thermometer was soaked in tepid water. But by changing the water in the reservoir frequently, and placing a fresh piece of muslin on about once a week, thoroughly satisfactory results were obtained, the wet bulb being further syringed daily with distilled water. The Richard hair hygrograph was employed as a check, so that any serious discrepancy between the two instruments was at once apparent. For measurement of the intensity of solar radiation a black bulb thermometer *in vacuo* was employed. This was fixed in a stand secured to the bridge in such a position that the sun could shine on it as nearly as possible at all hours of the day.

Two barometers of the new marine pattern were in use: one being placed in the deck laboratory at a height of seven feet above the sea, while the other was a spare instrument and was kept aft in the cabin. Three self-recording Richard barographs yielded continuous traces of barometric pressure. One of the late Dr. Black's marine rain-gauges was placed aft on the poop well clear of the deck. Its position was changed occasionally as circumstances arose, in order that it might always be on the weather side. The exposure—taking into account the various

difficulties attending rainfall observations at sea—was a very good one, as the gauge was never sheltered by the sails. The thickness of the rainband in the spectrum of sunlight was taken daily at noon, and the temperature of the sea surface was observed every four hours, and at more frequent intervals when rapid changes were in progress.

For ascertaining rapid fluctuations of the atmospheric pressure a Richard statoscope was employed; this is really an extremely delicate recording aneroid, in which changes of pressure are magnified twenty-five times. This instrument was also used for recording the height of waves. A chart put into motion by clockwork receives a trace of the pressure-fluctuations due to the rise and fall of the waves, the height of which could thus be calculated. Attempts were also made to fly kites for recording meteorological observations at high altitudes, but it was found difficult to get the kite clear away from the ship owing to eddies formed by the heavy masts, yards and rigging of a full-barque-rigged ship, although several of us were quite proficient in getting kites clear away from a small steamer which had less heavy rigging. Another drawback was that the speed of the *Scotia* was scarcely sufficient under some conditions to keep the kites flying well. It may be noted that Mr. John

Anderson, the pioneer of meteorological kite-work in Scotland, had equipped the Scottish Expedition with a small machine for reeling in the piano wire attached to box-shaped kites of the Blue Hill pattern. Specially constructed meteorographs, made of aluminium, were carried up by the kites, on which a record of the vertical distribution of pressure, temperature, and humidity was graphically recorded.

While mentioning this high-altitude equipment on board the *Scotia*, it is appropriate to refer to the splendid services the Prince of Monaco has rendered meteorology in the North Polar Regions by the use of kites and balloons. The author had the advantage of accompanying the Prince on three of his voyages to the north-west of Spitsbergen, and of assisting him in making these observations.

"The launching of a kite," says the Prince of Monaco ("Meteorological Researches in the High Atmosphere," *Scot. Geog. Mag.*, March 1907), "from a ship is always a delicate operation, and one which demands experience on account of the vortices found in the aërial wake of the ship, of which those visible in the aqueous wake are the image. Often when the apparatus has reached a height where it appears to be out of danger it may be caught by one of these risky vortices and precipitated

into the sea. In stormy weather such a catastrophe may occur even after the kite has risen to a height of several hundred metres.

"When the wind is strong enough and the bridle (the object of which is to keep the face of the kite to which it is attached horizontal) is not very exactly balanced, the kite at once executes plunging zigzag movements which may produce such a strain as to break the line. When the kites have reached the greatest altitude permitted by the circumstances, the paying out of the wire is stopped, and, either by increasing the speed of the ship, or by heaving in the wire as quickly as possible, a little final augmentation of height is obtained. The recovery of kites, although somewhat delicate, presents less difficulty than their dispatch. As at the launching of the kite, a subsidiary line is used, which is run alongside of the bridle as soon as this is got hold of, so as to limit the motions of the kite.

"Unfortunately, even with the greatest care, accidents occur." Five or six or even more kites may sometimes be attached one after the other along the wire. Should the kite and instruments fall into the water, "it is interesting to note that the curves furnished by our instruments can resist a prolonged immersion without suffering damage when they meet with such an accident. The curve

is a line traced by the pen on a layer of lamp black, deposited on the cylinder by the smoky flame of a petroleum lamp. In a case of immersion the carbonaceous particles disappear, but an excessively thin coating of grease, deposited with the carbon from the flame, remains, and the line traced by the point of the pen is clearly visible in it with a magnifying glass.

"A notable instance occurred during one of my earliest experiments in the Mediterranean in 1904. An instrument was lost to the northward of Corsica, and was found on the shore of Provence fifteen days later. The curves traced in the greasy film on the recording drum were still perfectly visible, and were utilised with the others in Professor Hergesell's laboratory.

"A kite operation, at a height of 3,000 to 5,000 metres, lasts almost the whole day, and the ship, which must at times steam full speed (the yacht *Princesse Alice* attains a maximum speed of 13 knots) in order to enable the kites to pass through zones of light wind or of calm, may easily cover a distance of 50 or 60 miles during the operation."

But, besides kite observations at high altitude, the Prince of Monaco has made some very remarkable investigations in the Arctic Regions by means of small balloons, which

he terms "*ballons-sonde*," which carry up instruments, and which, by several different ingenious devices, he recovers again. He has also made many valuable observations, by means of pilot balloons, which he has succeeded in following to the stupendous height of 97,700 feet, or 49½ miles from the surface of the earth, that is, three and a third times as high as the summit of Mount Everest —the highest mountain in the world.

After carrying on numerous investigations in the Mediterranean and in the North-east Trades, the Prince of Monaco in 1906 proceeded on his third voyage to the Arctic Regions, his destination being the Greenland Sea off the north-west of Spitsbergen. In Spitsbergen itself, he was to land a Scottish party under the author's leadership for the detailed survey of Prince Charles Foreland, and a Norwegian party under Captain Isachsen for the survey of part of the mainland; while he himself, associated with Professor Hergesell of Strasburg, was to explore the higher atmosphere. On July 13, 1906, I have interesting recollections of being one of a party of three, the other two being Professor Hergesell and Captain H. W. Carr, R.N.R., for so many years the Prince's commander and aide-de-camp, who conducted the theodolite work ashore at Deere Sound (recently erroneously called King's Bay), whilst the Prince

of Monaco was on board the *Princesse Alice*, attending to the liberation of a pilot balloon—the first that was ever set free in the Arctic Regions. While Professor Hergesell followed continuously the ever-ascending balloon with the theodolite telescope, Captain Carr and I were reading the vertical and horizontal limb of the theodolite and recording our synchronous observations. Knowing its ascensional force Professor Hergesell was able to calculate the course and altitude of the balloon, which reached a height of 26,050 feet, where a W.N.W. wind was blowing at the rate of 28 metres per second. The weather was clear, calm, and sunny, and gave a very good opportunity to carry out this series of observations in a thoroughly satisfactory manner.

During this interesting investigation of the atmosphere the Prince of Monaco was much hampered in carrying out his programme by persistent fogs over the sea to the westward of Spitsbergen, although in the bays and on the land the weather was magnificent. Thus the dispatch of "*ballons-sonde*" which the preliminary experiments in the Mediterranean had rendered perfect of execution was stopped by this insurmountable difficulty. Twice only was it possible to dispatch them. Nevertheless, the information received was very valuable, since the registering instru-

ment brought back curves from an altitude of 24,600 feet in latitude 78° 55′ N.

In this Arctic voyage the Prince had to resort to a new method on account of the constant presence of clouds which were down to a very low level although the horizon was clear, a condition that often prevails both in the Arctic and Antarctic Regions: this method allowed of a certain amount of exploration of the atmosphere though not so extensive as the method employed when the sky was cloudless, or when only detached clouds were present. The balloon was furnished with means capable only of taking it to such an altitude that it could regain the surface of the sea at a distance which does not exceed the limits of visibility. The ship is then stopped on the spot where the balloon was started, and attentive observers watch all directions in order to detect its return from above the clouds. One experiment of this kind that the Prince made succeeded perfectly, and the balloon, which had reached a height of 15,750 feet on a day when the sky was completely covered by very low clouds, was detected and recovered at a distance of twelve miles.

But the most remarkable results the Prince of Monaco has attained have been with pilot balloons. "These balloons," says the Prince, "which are small enough to be

embraced by the arms of a man, have been followed with a special theodolite to the extraordinary altitude of 29,800 metres (97,700 ft.), if it is assumed that their velocity of ascent increased a little with the change of density of the atmosphere in the most elevated regions; or at the very least to an altitude of 25,000 metres (82,000 ft.). Further, the one which attained this height was, at the moment of its disappearance, at a distance of 80 kilometres (49½ miles) from the observers. So remarkable a result is explained by the transparency of the atmosphere in the Arctic Regions, a transparency which, under other circumstances, permitted us to follow distinctly on the snow of a glacier, at a distance of 40 kilometres, the movements of a party of four persons whom I had sent on a mission of exploration in the interior of Spitsbergen."

This translucency of the atmosphere is a well-known character of the Polar Regions. Captain Armitage says, when the *Discovery* was off Cape Washington, Victoria Land, "the atmosphere was exceedingly clear, as may be imagined from the fact that we could plainly see Coulman Island and Mount Erebus at the same time, although they are 240 miles distant from one another." In Spitsbergen, at sea-level, I have seen the mountains on the south side of Bell Sound

from the north end of Prince Charles Foreland quite clearly—a distance of 100 miles; and I could quote many other instances of extraordinary visibility. The only comparison in temperate climates is from mountain tops: from the summit of Ben Nevis I have seen at one time the Black Isle and the waters of the Moray Firth, the Pentland Hills (or Arthur's Seat), Barra Head (100 miles distant), and the coast of Ireland (120 miles distant), though it is unlikely that one could ever see Ben Nevis from sea-level at Barra Head.

"The information furnished by the pilot balloons, which carry no instrument because they are sacrificed, concerns questions of capital importance for meteorology—the direction and the velocity of the upper currents. Now our pilot balloons of 1906 have taught us that there exist in the Arctic Regions in the neighbourhood of the 80th parallel, at a height of about 13,600 metres (44,600 ft.), certain winds of 60 metres per second (132 miles per hour), a force of which we have no equivalent at the surface of the globe. Their direction was S. 68° W."

The Prince of Monaco made thirty explorations of the high atmosphere in the Arctic Regions in the vicinity of Spitsbergen in 1906, and, in carrying out this work, added more to our knowledge, not only of the meteor-

ology of the Arctic Regions, but also of our knowledge of the meteorology of the world than almost any recent investigator. This is more especially the case because before and since he has carried out further extensive exploration of the upper atmosphere in the North-east Trades and in the Mediterranean, which can be correlated with the valuable work he accomplished in the Polar Regions.

CHAPTER IX

MAGNETISM, AURORA, AND TIDES

Almost every important recent Polar expedition that has set out for work extending over twelve months, has laid itself out to make a study of the magnetic conditions either of the Arctic or Antarctic Regions. The two polar ships that have been specially equipped recently for taking magnetic observations on board were the *Discovery* and the *Gauss*, upon which large sums of money were spent to secure a special area of the ship free of local magnetic influences. No other polar ships have ever been equipped so particularly in this direction, though many others, notably the *Erebus* and *Terror* in the Antarctic Regions, did a considerable amount of magnetic work. Recently the Carnegie Institution at Washington have fitted out a magnificently equipped non-magnetic sailing ship, the *Carnegie*, which is carrying out work of the highest importance in the form of a magnetic survey of the seas of the world. Unfortunately this fine ship does not appear to be fitted out for navigation

in ice, consequently this important survey must remain incomplete until some munificent millionaire resolves similarly to equip and endow a ship to complete the work by carrying out a systematic magnetic survey of the seas of the Arctic and Antarctic Regions.

But although so little has been done with regard to magnetism in polar seas, yet a very considerable amount has been done in polar lands. All the recent Antarctic expeditions carried out magnetic observations on land. The station set up by the Scottish Expedition in the South Orkneys has now conducted observations there continuously during the last eight years, thanks to the energy of Mr. W. G. Davis and the Government of the Argentine Republic. It is of interest to note that Sir James Ross, serving under his uncle Sir John Ross, was the first to take magnetic observations at the North Magnetic Pole, in 1831, and that Mr. D. Mawson, serving under Sir Ernest Shackleton, was the first to take magnetic observations at the South Magnetic Pole, in 1909. Though it is a matter of satisfaction to have the British flag hoisted in both magnetic poles of the globe, the intrinsic value of the observations taken there is not very great from a scientific standpoint, as Mawson himself points out, since they are only single isolated observations, but the good series of observations that Mawson has taken

in the neighbourhood of the South Magnetic Pole, as well as those of Bernacchi, are of the highest possible value. Further observations in circles round about the approximate point of each magnetic pole would add very much to our knowledge of terrestrial magnetism.

Terrestrial magnetism is altogether a most intricate and difficult science, but it is perfectly obvious that one very great use of an intimate study of this subject is for purposes of navigation. In the days of sailing ships, the finest course that was laid till recent years was to a quarter of a point or nearly three degrees of the circle, nowadays no steamer of any importance steers a wider course than one degree. The *Mauretania*, for instance, Captain W. T. Turner tells me, "is steered and the course set to degrees." In one instance, at least, I know of the captain of one liner insisting on an accuracy of a quarter of a degree, the helmsman keeping the course to that amount of accuracy by means of a magnifying glass placed over the compass card. With fine courses, such as those that are necessary for the high speeds attained, with the great value of these modern leviathans, with valuable cargoes, and with a thousand or more human beings on board, it will be seen how important an accurate knowledge of terrestrial magnetism is.

There is no more striking or wonderful phenomenon in the Polar Regions than the aurora—Aurora Borealis in the north and Aurora Australis in the south. Any one who has wintered in the Arctic Regions has had good opportunity of witnessing the aurora in all its splendour. It is not unknown in Europe during the dark winter nights, having been recorded as far south even as Italy, Spain and Portugal. It cannot, however, be regarded as a common phenomenon in southern Europe, and indeed does not become frequent until one reaches the latitude of the north of Scotland.

"Loomis and Fritz," says the late Dr. Alexander Buchan, "have severally investigated the geographical distribution of the Aurora Borealis. The region of greatest auroral action is an oval-shaped zone surrounding the North Pole, whose central line, *i. e.* the more or less elliptical line halfway between the northern and southern extension of the zone, crosses the meridian of Washington in latitude 56° and the meridian of St. Petersburg in latitude 71°. It follows from this that auroræ are more frequent in North America than in the same latitudes in Europe. Loomis points out that this auroral zone bears considerable resemblance to a magnetic parallel or line everywhere perpendicular to a magnetic meridian."

"It is a fact of the greatest significance that, as regards geographical distribution, auroræ and thunderstorms are complementary, auroræ being not more characteristically of polar than thunderstorms are of tropical origin; whereas thunderstorms may be regarded as completely dissociated from magnetic associations, and their periodicities are restricted to diurnal and annual variations" ("Aurora Borealis or Northern Lights," *Chambers' Encyclopedia*, 1901).

At Ben Nevis Observatory auroras have been frequently recorded, and indeed on many occasions there are very remarkable displays to be seen from the summit of that mountain. The most frequent form is a low arch of more or less elliptical form, rising not many degrees above the horizon to the north-west. On more than one occasion I have seen perfect coronas with their waving bands of streamers darting out from the zenith at times almost to the horizon. All the displays that I have seen on Ben Nevis had the streamers lighted with that lurid pale yellowish-green colour that every Arctic explorer is familiar with, but on one occasion at least there were mingled with it flashes of rosy red, which passed along the living bands. In Franz Josef Land during the winter of 1896–97 there were specially fine displays of auroras, and frequent observations were made upon them, by various members

of the expedition. Armitage, who conducted the magnetic work, found that the declination of the magnetic needle was disturbed by the presence of the aurora.

This interesting observation was by no means a new one, for in 1741 Celsius and Hiorter noted for the first time the simultaneity of the Aurora Borealis and the disturbances in magnetic declination. From 1741 to 1747 Hiorter recorded forty-six examples of this coincidence. At the suggestion of Celsius, Graham made corresponding observations in Britain, and it was found that the magnetic disturbances were synchronous on the same days in Sweden and Britain. These observations were followed up by Wargentin, Canton and Wilcke. Wilcke found that every time, or almost every time, there was a magnetic disturbance, that disturbance was accompanied by a display of Aurora Borealis; but the inverse was not found to be the case, that is to say, the Aurora Borealis might be observed without any disturbance of magnetic declination accompanying it. Between 1771 and 1774 Wilcke proved that the inclination of the needle was also affected, and that the centre of the corona corresponded with the magnetic zenith.

Humboldt, in 1806, discovered that there was a relationship between the magnetic force and the Aurora Borealis. In 1834 the

Magnetic Association founded by Gauss and Weber, and the stations organised by Sabine in many British colonies, multiplied examples of the relationship of auroræ and disturbances in the three elements of terrestrial magnetism, viz. declination, inclination, and intensity. These observations showed at the same time the extreme complexity of the subject. Some of the most interesting observations that have been made actually within the Polar Regions are those of Weyprecht, in the *Tegetthof* expedition to Franz Josef Land. Weyprecht noted that during these disturbances the declination needle was displaced towards the east, and that the horizontal intensity was diminished and the vertical intensity increased. Curiously, Parry near Melville Island and Port Bowen, not far from the Magnetic Pole, never recorded any relationship between displays of the Aurora Borealis and the movements of the magnetic needle. Ross, on the other hand, obtained opposite results in the same region, while M'Clintock and Kane's observations tend to confirm those of Parry. No relationship between these phenomena appears to have been recorded by the British expedition of 1875–76.

But Armitage says, in Franz Josef Land, "I could not avoid noticing the vagaries of the magnet, and attributing them to the frequent brilliant displays of auroral light

which held us entranced during our stay in the ice-bound North. More especially did the magnet appear to be affected when the aurora, rising in massive, thick arches from the eastward, and sending up streamers of beautifully coloured light, passed rapidly across our zenith and disappeared to the westward. . . . The magnet would oscillate wildly from side to side, or sometimes sheer rapidly to one side only, then as suddenly behave in a steady and normal manner." Armitage also noted that the most brilliant air effects took place during a "furious gale" or a "dead calm."

Buchan has pointed out that "Lemström has shown, by observations and experiments he made at Sodankylä, that auroræ are due to currents of positive electricity illuminating the atmosphere in their passage to the earth. Luminous appearances accompanied the setting in of a current towards the earth from the network of insulated wires with which he overspread the top of Mount Oratunturi, *and this light was clearly auroral*, giving the hitherto enigmatical citron line of Augström, which is the invariable constituent of aurora radiations. Other faint and indistinct lines are enumerated as present, and Lemström is of opinion that there is a tolerable agreement between some of these and the lines in the laboratory spectrum of rarefied air, but the whole subject demands further investigation."

Various theories have been advanced to account for the occurrence of auroræ, and among others has been suggested that the phenomena is due to the presence of cosmic dust. This, however, does not appear to be at all likely: in all probability it is a purely electric magnetic phenomena. It seems likely that the phenomena occurs in other planets than our own: it is known that the obscure hemisphere of Venus appears to be often illuminated, and Winnecke says that this illumination is of a greyish violet colour—in this connection it is interesting to note that these illuminations in Venus were especially observed during the years 1721, 1726, 1759, 1796, 1806, 1825, 1865 and 1871, and that 1726, 1759, 1865, and above all 1871, were notable years for the display of the Aurora Borealis.

One of the earliest theories put forward was in the middle of the thirteenth century in an old Norwegian book called the *King's Mirror*, where one quaintly reads, "Some people think that this light is a reflection of the fires which surround the seas to the north and to the south; others say that it is a reflection of the sun when it is below the horizon; I think, however, that it is produced by the ice which radiates during the night the light that it has absorbed during the day" (*Les Aurores Polaires*, by A. Angot, 1895).

The displays of aurora in Franz Josef Land during the winter 1896–97 were particularly brilliant and frequent. The usual display consisted of a series of waving ribbon bands like muslin frills, composed of vertical streamers in continuous motion, the streamers appearing to pass with varying intensity from end to end of these flowing ribbons covering almost every point of the sky; every now and then the streamers would shoot out to an immense length downwards towards the earth and far upwards towards the zenith, forming a corona from which all the rays that filled the whole sky appeared to originate. This coronal appearance is probably perspective effect, due to the enormous length of the shimmering rays. The general display of colour was exactly the same as has been described at Ben Nevis Observatory, but much more intense, and culminating during the most brilliant periods with flashes of emerald green, brilliant crimson, and delicate violet hues, which pass from end to end of the never-ending, ever-intertwining ribbons. It can scarcely be compared with any familiar object unless it be to an imaginary ballet in the sky, where the figures are in extraordinarily rapid motion, passing in continuous procession, one line of dancers mingling with another, and a series of flashlights of different colours passing rapidly across the tinselly muslin drapery.

The whole effect is weirdly beautiful, and has long been known in the Highlands of Scotland by the very fitting name of the "Merry Dancers."

It may be of interest to give one or two quotations from my diary when I was wintering in Franz Josef Land. On January 1, 1897, my log runs, "Auroras have been fairly frequent; I have not seen one like those I have seen at Ben Nevis in Scotland, where you get the distinctive arch or series of arches with streamers flowing along upward and darkness under the arch. One arch I have seen here, but not a perfect one, about six weeks ago. Within the dark area was the crescent moon to the southward. The arch at each end was flattened, or rather it was a semi-ellipse or such-like. No streamers flowed from the arch, it was rather a band than an arch. Here (except where there are simple bands, not the most general form) the streamers shoot downwards from the zenith and dance about in spiral waving arrangement. Sometimes there is a break between the lower ends of the streamers and the zenith, but still the streamers seem to continue as if in a line from the zenith or towards it." Writing on January 6, 1897, I say of the 3rd of January, "although there was fog and slight snow, there was a brilliant aurora quite lighting up the scene. A very

distinct shadow was thrown under my hand when placed 5 or 6 inches above the ground (snow). I have often seen auroras casting shadows here and lighting up the cliffs brilliantly. On the evening of the 3rd, at times streamers came playing brilliantly through the fog from the zenith, gambolling round and looking like brilliantly illuminated falling snow. The general impression I have received is that bands and collections of streamers have a more usual distribution across the zenith from east to west, but their directions are very varied."

On the 24th of January, 1897, at 9 p.m., I record "a band of aurora to-night from west-south-west to east, throwing up streamers toward the zenith. Curious appearance at east end being broken up like a very perfect type of fine cirro-cumulus cloud, looking as if illuminated by brilliant sun to the south-south-west; the band was broad and appeared to be crossing some cirrus clouds, and showed a mottled appearance. Here the dark portions were obviously due to cloud and aurora behind them, but to the eastward the cirro-cumulus sunlit appearance was, I believe, purely auroral. Wilton saw this, to whom I pointed it out."

"I have, on moonlight nights, seen aurora and cirro-stratus—one running into the other imperceptibly, not being able to tell with

absolute certainty whether it were cirro-stratus with aurora or aurora alone."

Many other quotations regarding aurora I have observed could be made, but these three sum up many characteristics not only for Franz Josef Land but for other parts of the Polar Regions—north and south.

It has been said that the aurora is accompanied by a crackling sound, but although carefully attentive for such a sound none of us ever heard it in Franz Josef Land, the opinion at the time being that such crackling sounds might be due to the crackling of ice and snow during an aurora, when there was also intense frost—the sound being caused by the frost, and not by the aurora.

So much for the Aurora Borealis with which every one who has wintered in the far north is so thoroughly familiar. There is a different story to be told in the south, where, during the two cruises and the wintering of the *Scotia*, not a single Aurora Australis was seen. Neither do the Swedish and French expeditions appear to have seen any definite displays of the aurora. Dr. Nordenskjold writes to me, saying, "We never did see any display of aurora at all during the time of our stay in the South, though looking always for such." Dr. Charcot says, "During both my expeditions, 1904 and 1909, we had once in 1904 and once in 1909 something

resembling an aurora, extremely faint, and uncertain if they had not been accompanied by magnetic perturbations. We had glares of pale green, which might have been attributed to auroras, but I really do not think they were. The two auroras showed themselves in the S.E." On the other hand, the English expedition in MacMurdo Sound had frequent displays during the whole time the *Discovery* wintered. "On the whole the displays, although very frequent, were extremely poor, and were generally in the following forms:" (1) Faint lights with no defined forms. (2) Luminous patches, which frequently presented the appearance of clouds. (3) Incomplete arcs, or segments of arcs, of which the brilliance was not uniform nor the border regular. From these arcs rays would frequently shoot up intermittently. (4) Rays, or vertical shafts, separated from each other at a greater or less distance, frequently described as streamers. (5) In one or two exceptional cases irregular bands, formed of rays or vertical shafts, pressed close together and forming "draped auroræ."

"The faint lines and luminous patches were of the most varied dimensions, sometimes very small and at other times occupying almost the whole of the eastern (geographical) sky; their brilliancy was rarely much more intense than that of stars of the 4th magnitude, or even the

Milky Way. They formed, as it were, a white veil over the sky through which stars of small magnitude were plainly visible. A clearly defined arc, formed of a homogeneous luminous mass touching the horizon at both extremities, was rarely seen."

"Spectroscopic observations of the auroræ were not successful, due, apparently, to the weak intensity of the light."

"The observations of atmospheric electricity taken during the displays reveal no special effect referable to the aurora."

"An examination of the journal shows that the largest number of auroræ occur during mid-winter months, June and July."

Although, on the whole, the displays of the aurora seen by the *Discovery* were extremely poor, and mostly straw colour, faint pink and green only having been observed on a very few occasions, Ross, in the same longitudes but farther to north, had brilliant displays on more than one occasion in February and March 1841.

It is very interesting to get a comparison of the Aurora Australis and Aurora Borealis by one who has seen brilliant displays of both, and in this connection Captain A. B. Armitage writes to me, saying, "The Aurora Australis could not hold a candle to the Aurora Borealis. I never saw colour so brilliant in the South as in the North; never did light

emanate from the auroral arches hovering over Victoria Land cast a shadow such as did the flickering streamers and coruscating coronæ of Franz Josef Land. In the North, too, I have seen the auroral light between me and a cliff 500 feet high and only 100 yards distant. I have seen stars of the third magnitude eclipsed by it and the moon's light pale before it; not so in the desolate South."

On March 23rd, Ross says, "Late in the evening we crossed the line of no variation in latitude 62° 0′ S. and longitude 135° 50′ E. At 7.20 p.m. observed a bright arch of the Aurora Australis west-north-west and east-south-east extending across the zenith, of a yellow colour, its edges tinged with a purple line. . . . The lustre of the larger stars was much dimmed as it passed over them, but they could be distinctly seen through it; some of the smaller stars were totally obscured by the brighter and denser portions of the aurora; this splendid display was, as usual, followed by a fall of snow."

On March 26th, Ross says, "The aurora again afforded us a considerable light at night, in the absence of the moon"; and again, "On the evening of the 27th we witnessed a most brilliant exhibition of Aurora Australis. . . . Before 10 o'clock bright streamers darted upwards from the cloud to the zenith, forming coronæ, and exhibiting bright flashes of all

the prismatic colours, green and red being the more frequent and conspicuous; this aurora had much motion, darting and quivering about the sky in rapid flights, and in every direction."

Rather in contradiction to Buchan's statement, Ross records, on the 28th of March, that "at 10 p.m. a single flash of forked lightning was seen in the north-north-east and at the same time an arch of aurora extended across the zenith from the horizon west-north-west and east-south-east; it was then blowing a strong north-westerly gale." Again, "The Aurora appeared in great brilliancy during the night of the 30th." Buchan's statement is, however, generally speaking correct, this being another of those cases illustrating how impossible it is to draw hard-and-fast lines in nature.

The study of tides is an important part of Polar exploration, and their study in Antarctic Regions more generally useful than in the Arctic Regions, for in the Great Southern Ocean lie the original tides of the world.

"The *Scotia* results," says Sir George Darwin, "are very valuable as relating to the only ocean uninterrupted by land throughout the whole circumference of the globe," and they acquire much importance when considered in connection with the very abnormal results obtained by the *Discovery*.

At Scotia Bay "the tides seem to be normal for a place in the Southern Ocean."

One of the most remarkable results of tidal observations taken in the Antarctic Regions, is the belief expressed by Sir George Darwin (*Proc. Roy. Soc.*, A, vol. 84, 1910) that those observations taken during Shackleton's expedition reveal a sea-seiche. These sea-seiches are known to exist in different parts of the world, and have been specially observed in many Japanese bays; but Sir George Darwin points out that in none of the examples given "has the seiche a period at all comparable with that of which we have reason to suspect the existence in the Antarctic Sea," namely, a three-day period. From these observations Darwin makes a "guess," and says, "I guess then that the bay behind the (Ross) barrier stretches past the South Pole and a little to the east of it as far as latitude 80°. Such an inlet would have a length of 25° to 30° of latitude. A sea of from 100 to 150 fathoms in such an immense bay as has been conjectured would oscillate with a period of three days, and the observed results are seen to be consistent with the existence of a deep inlet, almost or quite cutting the Antarctic continent in two."

"Such a conclusion is interesting, but it would not be right," Darwin wisely adds, "to attribute to it a high degree of proba-

bility, because there are elements of uncertainty on every side." Still it is one more of those intensely interesting Antarctic problems which emphasise how much need there is for further Polar exploration.

Tidal observations were taken on board the *Scotia* every half-hour from March 25th to November 23rd, 1903, when the ship was frozen in in Scotia Bay. The device adopted for recording the tides was a simple one. A heavy weight with an attached piece of sounding wire was lowered over the ship's side, through a hole in the ice-floe in which the *Scotia* was frozen, to the bottom, which was here 10 fathoms. This wire was led over a block suspended to a davit, and at the end of the wire, on board ship, a second lighter well-shaped weight with a horizontal base was attached, and was suspended in such a way that it rose and fell up and down the face of a wooden scale. The floe in which the *Scotia* was frozen moved with the tide, the height of which was thus shown by the position of the movable weight on the scale.

CHAPTER X

AIMS AND OBJECTS OF MODERN POLAR EXPLORATION

The world shrinks and now there are few parts of the globe which have not been traversed.

I say purposely *traversed*, for many parts traversed have not been explored. A race across Africa, from Paris to Pekin on a motor car, or what has been aptly called the "boyish Pole hunt," can now no longer be regarded as serious exploration. In fact, in Polar exploration especially, people are beginning to see the comparative uselessness of such journeys, and rarely can any Polar expedition get money unless the leader announces that such and such scientific investigations are to be made by a staff of experts, and that such and such scientific results are likely to accrue. Yet what the mass of the public desire is pure sensationalism, therefore the Polar explorer who attains the highest latitude and who has the powers of making a vivid picture of the difficulties and hardships involved will be regarded popularly as the hero, and will

seldom fail to add materially to his store of worldly welfare; while he who plods on an unknown tract of land or sea and works there in systematic and monographic style will probably not have such worldly success, unless his business capacity is such as to allow him to turn to his advantage products of commercial value in the lands and seas he has been exploring.

The general rule, however, is that the man of science opens the way and reveals the treasures of the unknown, and the man of business follows and reaps the commercial advantage, and where this is not the case and the man of science takes to money-making, the chances are that the world has rather lost than gained by his transition. It is right, therefore, that the man of science who has not the time or the inclination to devote his life to the gathering of gold should look to those who have this for their chief aim in life to support him in investigations of the unknown, or to those who, by the industry of their ancestors, have more than is necessary for at least a life of comfort.

In the face of these facts it is interesting to note that there are men of great wealth and of no narrow interests who nevertheless declare that they cannot see the use of such expeditions.

Exactly the same encouragement that

Columbus received more than four centuries ago! Was there ever a more madcap expedition than that one? A veritable nutshell was to sail westward into the unknown and was to face dangers beyond all the powers of human conception.

If there is not wealth equal to that of the New World of Christopher Columbus, there is no reason to suppose that very great wealth does not exist in the Polar Regions, considering the increased power given to man by the advancement of science, which is constantly showing new ways and means for discovering and making use of Nature's resources.

So far I have been trying to answer the question which the Polar explorer constantly gets asked him by the business man who has not had any scientific training, viz.: What is the use of these Polar expeditions? If the sole aim is to reach the North or the South Pole, or to get nearer to it than any one has been before, the answer must be that it is of little value either to science or commerce. That is the accomplishment of an athletic feat only to be carried out by those who have splendid physical development. But if it refers to expeditions well equipped with every means for the scientific survey of a definite section of the world—be it land or sea—then the answer is different. To add to the store of human knowledge means increased power

of adding to human comfort. It also means making another step into the forever unfathomable unknown, and it is the duty of the scientific explorer as a pioneer to investigate a definite area of the unknown with a staff of competent specialists.

Modern Polar exploration must be conducted in this manner. Having decided whether one's energies are to be applied to the Arctic or Antarctic Regions, the explorer has to make up his mind whether it be land or sea that he is about to explore, and, having determined that, and being well acquainted with the literature of his subject, and having had previous practical training in the work he is about to undertake, he chooses his definite area. It may be a large or a small area. It may be one that has been previously traversed and of which a hazy idea may be had. It may be over lands untrodden by the foot of man or seas as yet unfathomed. Suppose it is a detailed investigation of the North Polar Basin. The explorer must first have a good ship, built somewhat on the lines of the *Scotia* or *Fram*, for resisting and evading ice pressure, and, following the idea of Nansen's drift, he will sail for the Behring Straits, making his base of departure British Columbia or Japan. Then working northward as far as possible through the pack ice, the ship will eventually be beset firmly in the autumn or even earlier,

and, if she be of the right build, with safety. Now, as far as the ship is concerned, she must be made snug for the winter, and she becomes to all intents and purposes a house for the next three, or maybe four, years. She will drift right across the North Polar Basin, and will emerge from the Polar pack somewhere between Greenland and Spitsbergen. The probability is that she will pass almost if not right through the position of the North Pole. But all this may be counted worthless if there is not complete and thorough equipment of men, instruments, and other material for scientific investigation. The expedition must be for the thorough examination of the Polar Basin—that is, it must be an expedition fitted out primarily for oceanographical research. The leader of the expedition should be a scientific man, and should certainly be one who has gained knowledge by having carried on scientific research in one or more departments in the service of some previous expedition. He must also be practically acquainted with the handling of an oceanographical ship. Without such experience, be he landsman or seaman, failure must be the result.

The scientific staff must include well-trained men able to organise the work of their various departments under the co-ordination of the leader. Astronomy; meteorology, including an investigation of the higher atmosphere

by means of balloons and kites, as well as sea-level observations; magnetism; ocean physics, including an investigation of currents, temperature, specific gravity at all depths from the surface to the bottom; bathymetry, including a complete study of the shape of the floor of the Polar Basin; geology, especially a study of the nature of the bottom; biology, an investigation of every living thing, those animals that live on the bottom of the sea, those who swim on or near the surface or in intermediate depths—in short, benthoic, planktonic and nektonic research; a study of the algæ and animals that may be found in association with the ice itself, as well as an investigation of every animal or plant above the surface of the ocean. Six or eight scientific men would not be too few to form the scientific staff, and they must be provided with at least two laboratories, a scientific storeroom, and photographic room. The leader himself being well acquainted with conditions of work in the Polar Regions, it is not essential that the scientific staff should be, but it would be an advantage that his chief-of-staff had some ice experience, and that he should be able to take up the reins in the event of the serious illness or death of the leader. The scientific side of the ship should be separate from the nautical, and the leader must be the intermediary and guiding hand for both. The master of the

ship must be subject to the leader, and the crew entirely responsible to the master, the leader strongly supporting the master in this position. It is questionable how far commercial advantage would be derived from such an expedition, probably none immediately, though almost certainly some to a future generation if not to our own. But the increase of human knowledge by the thorough survey of a definite area of our globe in a systematic manner is sufficient to warrant such an expedition being carried out.

This is the chief piece of work (in the North Polar Regions) that remains to be done on an extensive scale, and which must extend over a long period of time without a break, and it is understood that this forms more or less the programme of Captain Amundsen, who left Norway in 1910, although by telegrams received on the outward voyage of the *Fram*, which is his ship, it appears doubtful whether he is not going to confine his attentions to the Antarctic Regions instead! But there is much Arctic work to be done in other directions, such as, for instance, the work that the Prince of Monaco has been carrying on in the exploration of the upper atmosphere, or the detailed survey of a definite area of land or sea, and general oceanographical research; also such detailed survey work as has been carried out by the three Scottish Expeditions during the years

1906, 1907, 1909, in Prince Charles Foreland. (See *Scottish Geographical Magazine*, vol. xxii, 1906, p. 385; vol. xxiii, 1907, pp. 141–156, 319, 490.) This island, about 54 miles long and about 6 miles wide, forms a considerable part of the west coast of the archipelago of Spitsbergen. Prince Charles Foreland, named after Charles, son of James VI of Scotland, has been known to exist for more than 300 years, yet there has been practically complete ignorance of its form, geology, fauna and flora. Ships passing fear to approach its coasts on account of unknown and often imaginary dangers. Science demanded thorough investigation of this unknown land, and some have been trying to satisfy this demand of the world of science. What is the result? Already, before the work is complete, commerce has followed on the heels of science, and before the Scots left the island in 1907, Norwegian hunters set up three houses for the winter. The Scottish Expedition carried on a considerable amount of local hydrographic work, especially in Foul Sound and in the vicinity of some of the anchorages, and now ships can approach with greater safety the coasts of this previously unknown land which, until recently, they have justly feared so much. Many other instances of work of this kind could be quoted that have been carried on during recent years and is still

being continued. Leigh Smith, Baron Nordenskjold, Nansen, Nathorst, the Prince of Monaco, the Duke of Orleans, and Amundsen may be numbered among others as pioneers of systematic scientific research in the Arctic Regions.

It would be of interest to take the chart of the Arctic Regions and to enumerate the different parts that yet remain to be explored —their name is legion. The Beaufort Sea, and the islands and channels to the north of the American continent, offer especially a splendid field for topographical, hydrographical, biological, geological and other research. Much valuable work is to be accomplished by a series of stations set up in strategic places for biological research, and the same may be said for magnetism and meteorology—especially if associated with investigation of the higher atmosphere. Denmark deserves great credit for recently setting up a biological station in Davis Strait in the manner here indicated. This has been accomplished by the generosity of Justice A. Hoek, and is backed up by an annual grant of £600 from the Danish Government towards its maintenance (*Scottish Geographical Magazine*, vol. xxi, No. 2, 1905; No. 5, 1905; vol. xxii, No. 4, 1906). Similar stations could with little difficulty be set up in Spitsbergen, Franz Josef Land, Novaya Zemlya, and possibly also

in Jan Mayen, East Greenland, and the shores of northern Canada and Siberia. This form of research is one of the most valuable forms of exploration yet to be accomplished. The station should in each case be provided with a moderate-sized steam or motor launch.

Now, turning our attention to the South Polar Regions, we find the most interesting field in the world for exploration, especially with modern methods. Almost everything south of 40° S. requires thorough investigation and overhauling, and vast stores of information are to be gathered both from sea and land. And let us not neglect too much the sea, more especially since we are a seafaring and sea-loving nation. The pride and glory of our past is largely due to the intrepidity and alertness of our seamen. Yet with all this, not only the public generally, but even many scientific people think much more of an accidental discovery of land than of any amount of hard, plodding work carried on at sea. So much so that if an expedition investigates 150 miles of unknown land it is said to have made "important geographical discoveries," whereas, if it investigate, with equal if not greater detail, 150 miles of unknown sea, it will be said that the expedition made "no geographical discoveries." The reason is that, especially in Britain, few people really appreciate a map, so notoriously

bad is the teaching of geography and so little is it encouraged. The ordinary atlas simply paints a blue colour over the surface of the sea, and will give for its series of special maps political land areas, and these even without any interpretation of the "why" and the "wherefore." In these maps care is taken to omit as much of the sea as possible compatible with a certain rectangular space, and the sea that is shown is merely a meaningless pale blue wash. Scarcely any attempt whatever is made to show whether these stretches of sea are deep or shallow, clear or muddy, brown or blue, rough or smooth; there are few indications of currents—tidal or otherwise. In many ways, in spite of an increasing number of scientific ships sailing over the ocean, we tend not only to care less and less about the sea, but actually in some ways to know less about it. To the great 20,000-ton leviathan going twenty to twenty-five knots, weather conditions, currents, etc., of vital importance to smaller and less powerful craft are of little significance—these monsters race through everything. The thousands of passengers in these ships make a voyage and know no more about the sea over which they have travelled than if they had been staying in a palatial hotel ashore. In these days ships go on definite tracks and repeat their voyage year after year over exactly the same

narrow belt of sea; those on board know nothing of the ocean outside that belt of 30 miles in breadth. In the old days sailing vessels were driven hundreds and even thousands of miles off direct tracks, and saw actually much more than we do nowadays, especially since the vessels were slower and smaller, and the surface of the sea more readily accessible to those on board. Thus the stories of great sea monsters might not be so fabulous as supposed, though those in small craft and without scientific training might possibly get a somewhat exaggerated idea of their size and shape.

In the Antarctic and subantarctic Regions great opportunities present themselves both for a study of the sea and the land, and to the writer's mind it is a study of the subantarctic and then Antarctic seas that is at present most urgent, including an exploration and definition of the southern borders of those seas.

I say, designedly, the southern borders of those seas, and not the outline of Antarctica or the coast-line of the Antarctic continent, because it is from the oceanographical standpoint that I believe we should make this attack in the first place and to a much larger extent than heretofore. The early navigators attacked the south in this manner, and, more recently, with modern scientific methods,

the *Challenger*, *Valdivia*, *Belgica*, *Scotia* and *Pourquoi-pas?*. Only the last three vessels have done serious biological and physical work south of the Antarctic Circle, and the *Scotia* alone in the great depths in very high southern latitudes.

More than anything that is required is a new expedition on the same lines as the *Scotia*, and the author is ready to organise such an expedition as soon as funds are provided. Such an expedition should be provided with one ship of about 250 to 300 tons register, and should carry a complement of about thirty-six men, including six men of science. The vessel must be provided with all the most modern oceanographical equipment, and must be prepared to work in depths exceeding 3,000 fathoms. A definite area must be selected, and I should choose for the new Scottish Expedition, which hopes to set sail in 1912, the region south of 40° S. in the South Atlantic Ocean, avoiding the tracks of the Scottish National Antarctic Expedition in 1902–4, but complementing and supplementing the *Scotia* explorations. A suitable base from which to commence operations is Buenos Aires. A start from there should be made in the early spring—say not later than August 1st—a zigzag course under sail could then be steered between latitudes 40° S. and 55° S., a visit to Gough Island and

the other islands of the Tristan d'Acunha Group being included; a double or treble line of soundings, with a regular series of physical observations at each station, should be made, and the trawl should be lowered two or three times every week. No haste is required on this voyage; the vessel would be going before the westerly winds under sail the whole time, coal being husbanded for handling the vessel during sounding, trawling, etc. Cape Town would be the first port of call, and thus a belt of 1,000 miles in width, over 3,500 miles in length would be covered, where (with the exception of some soundings and trawlings made by the *Scotia* in 1904) no oceanographical work has been done at all. Whilst crossing the "Scotia Rise," which the Scottish Expedition discovered as an extension of the Mid-Atlantic rise 1,000 miles farther to the south, it would be interesting and important to attempt by means of grippers to obtain samples of the rocks *in situ* of which this rise is built. At Cape Town all the scientific material and the first copy of the scientific logs should be sent home in case of accident to the ship in her second voyage, a precaution that should always be taken by every expedition. The ship and all her gear would be thoroughly overhauled, and she would be filled up with coal and provisions. Her next course would be for the South Sandwich Group, and an arrange-

ment should be made for a vessel with coal and fresh food to meet her there. Here the special object is to carry on the bathymetrical survey in the region where opinion is divided as to whether deep or relatively shallow water exists, namely, that portion cautiously marked in the Scottish chart (*Scottish Geographical Magazine*, vol. xxi, 1905, pp. 402–412) lying between the south end of the "Scotia Rise" and the Sandwich Group. This is of vital importance in the study of continental connections. A short time would be spent in the South Sandwich Group, especially with a view of obtaining a knowledge of the geology and natural history of the islands. Having filled up with coal, a cruise eastward to Bouvet Island should be made to determine more definitely whether or no there is a "rise connection" between the Sandwich Group and that island, and also with the south end of the "Scotia Rise." From Bouvet Island a southerly course should be steered towards the southern boundary of the Biscoe Sea and a thorough connection made between the *Valdivia* and *Scotia* bathymetrical surveys. In March it would be necessary to decide whether the expedition was to winter in the south, but in no circumstances, if it can possibly be avoided, should the ship winter. She is there for oceanographical research, and must not be turned into a harbour hulk. Accidents

will happen, and she might be beset and forced to winter, for which she must be thoroughly prepared. But if there is a wintering, it should, if possible, be by a party of about half-a-dozen men in a house on shore.

This project for Antarctic exploration does not lend itself in the least to the attainment of a high latitude. It is almost certain, in fact, that the ship in question would not pass the 75th parallel of latitude, and it is more than probable that it would pass little beyond 70° S., but there is no doubt that for systematic serious scientific work, this would be one of the most profitable forms of Antarctic exploration that we could undertake. A single example is again taken of what is to be done in Antarctic seas, but it might be pointed out that half-a-dozen ships doing this same work in similar but different areas all round the South Pole would all obtain results of the highest importance.

As regards land work in the Antarctic Regions, this can be undertaken more satisfactorily after we have obtained a more definite idea of the confines of the Great Southern Ocean around Antarctica. At present there is too much hazy conjecture, and we find what one believes to be part of Antarctica itself another declares to be an island. But the land work has begun, and to the keen landsman there is no reason why

it should not be going ahead. In the past the splendid land journeys of Scott and Armitage have given us the first definite idea of the interior of Antarctica, and Shackleton has been able to make further most important additions to our knowledge of the interior of the Antarctic continent. Similar inland as well as shore expeditions, such as that suggested by Dr. Forbes Mackay (*Geographical Journal*, January 1911), should be made at many points all round the Antarctic continent, but any expedition of this kind must necessarily have a good base station and be supported by a ship. The retention of a ship at the base is entirely unnecessary, though, as indicated previously, ice conditions might unwillingly entrap the vessel, in which case she must be properly prepared for wintering.

Valuable land work could be carried out by a party accompanying this expedition to the Weddell and Biscoe Seas. Here the coast-line of Antarctica will probably be found to lie somewhere between 70° S. and 75° S. and to run in a more or less east and west direction. Having found a suitable anchorage, and the house being set up with a complete establishment for meteorology, magnetism, biology, and other scientific investigations, the party would make inland excursions towards the south. Should there be sufficient funds, it would be well to have

a second ship for the express purpose of carrying an extra supply of stores and a house, rather than lumber up the oceanographical ship with all this material. If the lie of the land be found to be as expected, a serious attempt would be made to cross the Antarctic Continent and to emerge somewhere along the coast of the Ross Sea, the journey being made more or less along the meridian of Greenwich on the Atlantic side, and continuing on about the 180th meridian on the Pacific side. Such a journey would be of more intrinsic value than a journey towards the South Pole and back. It would give a complete sectional idea of the continent of Antarctica, and the expedition would never be covering the same ground a second time. This is a big project, and one would have to face the chances of failure, but it ought to be attempted. Already England and Japan are in the field, and Germany and Australia are ready to start, and it is hoped that Scotland once more will shortly be enabled to join hands in co-operative exploration to the Antarctic Regions. Shackleton and Scott have wisely led the way by actually trying motor power, which the author has been advocating for many years, for the accomplishment of such a journey. It is an experiment; it may fail, but it is more likely to succeed, and even if it fails it will be one step in advance towards the use

of motor power in future Polar expeditions. All such pioneer attempts must take their chance of success or failure in a new application given to us by the advance of science.

This area, where Bellingshausen and Biscoe almost a century ago have alone given us a clue, strengthened by the investigations of Ross and of the *Scotia*, offers an especially fine field for meteorological and magnetical research. This is because of the systematised series of meteorological stations which exist to the north-westward of the region right up to the South American continent—thanks to the efforts of the *Scotia* and of the energetic Argentine Republic that has backed up and continued the work of that expedition. Such an expedition will give a very complete idea of the meteorology and magnetism of the South Polar Regions in all western longitudes, and in meteorology especially is required a systematic and synchronous series of observations such as are here indicated.

The world shrinks, but, after all, this is only from the point of view of those who do not look into futurity. Each scientific investigation leads to the discovery of new scientific facts and problems not only unknown, but often entirely unconceived. Newer and wider fields for investigation will offer themselves in the future than in the past; rather, then, should we say, the world expands!

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